PSYCHOLOGY
OF THE
OTHER-ONE

AN INTRODUCTORY TEXT-BOOK
OF
PSYCHOLOGY

BY

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PREFACE

The present book is the result of the necessity, existing in some colleges and universities, of giving elementary instruction in modern psychology to college students who are only members of the freshman class, to students who have never studied psychology before, to students who may never study it later, to students who have little knowledge of physics and chemistry and perhaps still less of biology, to students who take an elementary course in psychology in order to take afterwards a course in educational psychology, and to students who want elementary psychology for a better understanding of the problems of the social sciences. For these classes of college students this book is written as a text to be elaborated by the instructor as he wishes, by the aid of lectures, additional reading assignments, or laboratory work.

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PSYCHOLOGY OF THE OTHER-ONE

CHAPTER I

The Other-One becomes an Object of Interest to Us.

Robinson Crusoe has just acquired his man Friday. He is naturally anxious to know what use he can make of his new acquisition. So he goes to the Public Library (this is a sort of Munchhausen tale) and selects the present book as the one most likely to give him the desired information about "The Other-One."

In times past one used to turn to psychology books when he wanted to learn something about his Self—his Soul. There are even recently printed psychology books which bear the title "The Science of Selves." This very title is an anachronism. The idea of a Self characterizes in every branch of science what one might call its "prehistoric" period. Man tried in vain to explain the heavenly bodies, the weather, the land, the water, the animals and the plants by regarding them as Selves: Jupiter, Apollo, Neptune, and so forth. Modern science owes its triumphs to the fact that it has learned to restrict itself to describing merely that which one can measure. The psychology of the Other-One follows the same road. Why should Robinson Crusoe, wanting information, use the antiquated, the sterile method?

Measuring means always comparing and counting—comparing a thing by means of our sense organs with another thing which we regard as our standard unit, and counting the number of units. Without the application of our sense organs there is no measuring.

There is a special fact which has greatly retarded the advancement of the psychology of the Other-One,—the fact that the psychology of the Self appears so much easier, so much more promising.

Robinson Crusoe, when asked, tells us eagerly that he knows perfectly that he has a Self, a Soul. He adds that he knows this Soul, this mind, this Consciousness (we capitalize in order to show our proper respect) much better and also with even greater certainty ("Cogito, ergo sum," said Descartes two centuries ago) than any of the things of the world. The latter he does not know so directly, but merely indirectly, thru mediation of his sense organs. But for exactly this reason it seems useless to try to teach him anything about what he knows so well, his Self. On the other hand, he admits that he knows his man Friday only by applying his sense organs to Friday; that *without applying his sense organs he would not know that his man Friday existed.*

Therefore Crusoe's desire to know as much more as possible about his man Friday cannot be satisfied by the psychology of Selves. He needs the psychology of the Other-One. He needs the psychology which applies sense organs to the object of study, compares what the sense organs perceive, counts and—leaves the question whether Friday has a Self, a Soul, a Mind, a Consciousness to the single being whom it might concern, to Friday.

It is customary that in such a critical case the Devil is also present. (He always tries, as is well known, to embarrass people if he has a chance.) He is present on the Island clothed as a missionary. He approaches Crusoe with this impertinent question: "Are you going to deny, by selecting this book on the psychology of the Other-One, that your man Friday has a soul, precious and immortal?"

Crusoe replies: "If I were a missionary and interested chiefly in the saving of a soul, the question, whether he has one or not, would be of the greatest importance to me. But I merely desire to know what use I can make of him benefiting me and also benefiting him so far as I can know thru my sense organs what may be good for both of us. This I may be able to learn from the psychology of the Other-One. Your question is irrelevant.

The Devil changes his clothes and reappears as a philosopher. "Crusoe," he says, "don't you admit that one can draw conclusions relative to things he has never seen?"—"Himself," shouts Crusoe, as the Devil has barely finished his sentence. "You left out the word himself at the end of your question. What others have seen, may take the place of what I have not seen myself, because it is inconvenient to look at many things myself. But this does not change the fact that my interest in Friday is restricted to what my or other sense organs reveal. Without any sense organs existing in this world, nobody would conclude that this man Friday existed and add his existence to the stock of scientific knowledge."—"It is true, then, what has been rumored," continues the Devil, "that you take no interest in your man's spiritual welfare, that you are irreligious, and that you have driven the missionary from this Island?"—"What a defamation!" replies Crusoe indignantly. "What is true is merely that I refuse to mix up my scientific interest with my endeavors in religion, poetry and art."

Before entering into a detailed study of the Other-One, Crusoe thinks it advisable to trace in bold outlines the various roads over which he has to travel in reading his book. Let us, he says, compare the Other-One with animals, plants, manufactured engines. Watching him only a few weeks or even only days, we convince ourselves that his

chief distinction consists in being, not manufactured of virtually changeless materials, as an engine is, but a product of growth, and that he continues to grow in many respects.

With plants the Other-One has growth in common. But the differences are immense. First let us note his much greater motility. We can use the term activity instead of motility and then speak of his greater activity. Concerning his activity, however, there is a distinction which is not merely one of more or less. The activity of a plant is, so to speak, stereotyped. A certain plant closes its petals whenever is is placed in the shade. The Other-One's action—like the actions of virtually all animals—may for some time appear to us to be stereotyped, too. But suddenly we observe that an unexpected and novel action occurs. For example, Crusoe gives Friday a piece of meat and finds that he puts this in his mouth and swallows it, gives him a piece of bread and finds that he puts it in his mouth and swallows it. He gives him a piece of chocolate and finds that he puts this in his mouths and swallows it, too. He gives him a piece of chewing tobacco and finds that Friday puts it in his mouth and spits it out. But Crusoe remembers that, when he gave his uncle a piece of chewing tobacco, this Other-One kept it in his mouth for a long time. Generally speaking, the Other-One seems to be capricious, willful.

Comparing the Other-One with animals, Crusoe discovers that Friday often, especially before performing some important action, talks to himself; and that sometimes he also makes curious signs in the sand, and that this talking and writing seems to have a great influence on what the particular kind of action is which follows. For example, he finds him doing this before he chooses a particular kind of material and a particular spot on the Island for the con-

struction of a shelter. The Other-One's actions, far from being directly in response to the surrounding things, are often—indeed usually—mediated by a self-created, that is, invented, set of symbols. Some call these symbols "thought;" some call them more objectively "language." Comparing the Other-One with animals, we can say then that he is thoughtful.

Recapitulating: The Other-One is more a product of growth than this can be said of an engine or its parts, and has growth in common with plants. The Other-One differs from plants thru his willfulness, his variability of action, which he has in common with animals. The Other-One differs from animals by his thoughtfulness, the mediation of many or most of his actions by symbols, which makes him the lord of the Earth.

For the reasons which follow one may speak of a hierarchy of these three functions: thoughtfulness, the highest; willfulness, lower; growth, the lowest. And one is then justified in calling the Other-One the highest creature in the universe, an animal a creature less high, a plant a lower creature, an engine still lower.

Thoughtfulness is not possible without willfulness, for the invention of arbitrary symbols naturally is a function of willfulness, is a kind of variation of a being's reaction to its surroundings. A stereotyped reaction could not be called an invention. And willfulness does not seem possible to any considerable extent without growth, for the variability of action is—altho not absolutely, since an engine, too, may surprise us; at least in a growing thing, in a product of growth—dependent on growth. Nobody who has the slighest experience with human and animal willfulness denies that it is the result of a kind of growth, both in the race and in the individual. Robinson Crusoe, in order to

know all he can about his man Friday, will ask us two questions. I. What part of his body is it on whose growth first his willfulness, later his thoughtfulness, depends? II. What are the peculiarities of the growth of that part of his body?

A popular answer to the first question would be—the brain. A better answer would be—the neural, or nervous, tissue. The brain is simply a conspicuous lump of nervous tissue, but not all of it. In its totality we customarily call the nervous tissue "the nervous system." The answer to the second question cannot be given briefly. We shall have to proceed for it thru many chapters of this book.

On reading the last paragraph it occurs to Robinson Crusoe to ask himself if he did not make a mistake in selecting this book. Are there not many other kinds of books which give information, and perhaps better information, on the nature, the life, of the Other-One? Physiology, anatomy, sociology, economics and other sciences which we meet in any university catalog are also concerned with the Other-One's life. Does this book on psychology, when it applies itself to the study of the Other-One's life, encroach upon these other sciences?—No! There is undoubtedly some, but no more, overlapping between psychology and these other sciences than there is between many other two sciences picked out of the catalog.

What sufficiently divides the problems of the psychologist from those of the physiologist or anatomist is the greater social or individual significance of their problems. A stomach ache or a deformed bone are undoubtedly problems of the Other-One's life; but they concern chiefly him, who has them. If you pass this man or woman on the street, it makes little difference to you whether he suffers from the ache or not, whether she limps or not. These scientific

problems of the Other-One's life, as problems of mainly individual concern, are problems of the physiologist, who studies digestion, of the anatomist, who studies the structure of the bones. On the other hand, a man whose "life" at this moment consists in striking with his fist another man's face, is a problem which concerns you immensely, even if you are a mere bystander, but still more if you are the one whose face is afflicted. The peculiar muscular contractions in the fighter's arm and body in general, being of social rather than of individual significance—the lone Robinson Crusoe on his island in the past could not fight—are a problem of the psychologist.

Having thus drawn a line between the problems of the physiologist and those of the psychologist which is quite sharp enough for all practical purposes of departmental organization in our scientific institutions of teaching and research, we find it no more difficult to draw a line between psychology and those other sciences of the Other-One's life whose problems are also characterized by their social significance. Psychology is not concerned with special social institutions—the other, the special social sciences, are exactly thus concerned. Marriage, for example, is a social institution quite differently specialized in different parts of the world. The sociologist studies the different forms of this relation of the sexes as it appears among Americans, Turks, Chinamen, Hottentots and so forth. The psychologist is interested in marriage only to the extent to which its features are common to the Americans, the Hottentots and all the other human beings on earth. The psychologist is interested only in the fundamental laws of the Other-One's life, not in the special forms which these laws take when applied to particular historical, geographical or ethnological conditions. Like marriage, punishment of crime is a social

institution and as such an important object of interest to the sociologist. The psychologist studies this problem of punishment of human beings by other human beings only in its fundamental aspects, in those aspects which are the same in every human being no matter in what country and in what historical period that being lives. The psychologist will hardly offer advice to the American nation today as to how it should reform its penal institutions. That is the sociologist's business. Another immensely important group of social institutions are the schools. The special problems, however, of the age at which a child should be sent to school, what subject should be taught first, what later, are problems which the psychologist gladly and without any feeling of jealousy leaves to educational science. Let the educator decide how children should be guided to grow into citizenship, the psychologist finds problems enough, of a more fundamental nature, concerning the general possibility of changing the raw material, so to speak, of the Other-One as produced by heredity into a creature properly adapted to any environment for which Nature neglected to make—could not make—satisfactory provision by heredity. What the psychologist studies is the general possibility of adaptation to any form of environment, no matter what it might be, leaving out of consideration all those historically conditioned needs which are the very crux of the problems of the educational scientist. Political science, to give one more example, is interested in government. This is another social institution of specialized kind. The psychologist gladly leaves the study of government to political science.

Robinson Crusoe thus convinces himself that psychology is the study of human life in a material sense, that is, the study of the life of the Other-One,—but of his life in so far as it is of social significance rather than as it is of sig-

nificance for himself, and only in so far as life, in its social aspects, is the life common to all his brothers on earth. Thus is excluded from the province of this study the Other-One's life as it shapes itself under special social institutions.

If we call psychology a Natural Science, it is the study merely of the nature of "the Other-One in relation to us." And if we call psychology a Social Science, it is the fundamental social science. The social sciences in the common use of this term must then be regarded more properly as the "special" or "applied" social sciences.

Looking now at the Other-One, at animals, and at plants (all three the product of growth) from the psychologist's point of view as we have just come to understand it, we can not help being struck by the fact that plants are distinctly unsocial, animals distinctly social beings. We hardly think of "The Lonesome Pine" of the Kentucky mountain trail as being an abnormally living specimen of its kind, but we cannot think of the lonesome Robinson Crusoe on his island as living a normal life. Animals mix because they move. Locomotion is their most characteristic form of behavior. Exceptions to this rule, of plants being stationary and animals locomotive, strike us so forcibly by reason of their being distinctly exceptions. And even such cases are exceptions usually only during a part of their lives, such as the oyster which indeed moves about during the early part of its life and settles down to a hermit's life only when older. The relative necessity of locomotion for animals, the lack of this necessity for plants is clearly connected with the fact that only the plants can stretch out their roots and limbs, the organs thru which they obtain food, more and more the longer they live. So far as their limbs are concerned, this means no more than an enlargement of the receptive surface exposed to the air and the light. But the growth of the

roots means more than an enlargement of the receptive surface. The motion of the soil liquid thru the capillaries of the soil is immensely restricted in comparsion with the motion of the air. There would be an approach to exhaustion of the nutritive elements of the soil needed by the roots if the roots did not penetrate into ever new portions of the soil, where the possibility of exhaustion is yet far removed. The animal, however, not having roots, must move bodily to another place when it has consumed all the food obtainable at its present locality.

So we can say that Nature must have endowed, and has endowed, animals with the means of locomotion. The animal moves on when for some time no food has been taken into the digestive cavity, there being no more food available. Let us not say that the animal moves because it is hungry. We are trying to get information about the Other-One and about everything material (animals, plants, engines and what not) to which he might be compared and thereby become clearer to us. Now, we do not say that a plant extends its roots because it is hungry. There is no need for saying this with reference to an animal either. And no need even with respect to the Other-One. Nothing is gained thereby, unless anyone thinks that something is gained, for example, in an analogous case by speaking of the sea as the hungry Neptune. Nothing becomes clearer. The animal moves because for some time no food has been taken into the digestive cavity. This is clear enough. Nature's purpose in the motion is to remove the animal from the place where there is no food to other places where there may be food.

This purpose can be served most efficiently if the locomotion is motion in a straight line, for motion in curves, in serpentines, in zig-zag lines would not bring the animal so

quickly, with so little expenditure of energy of the living body, from the first place to a second place removed from the first possibly a considerable distance. The act of locomotion, therefore, a form of behavior called forth by the stimulus of lack of food, is locomotion in a straight line. We must not regard it as astonishing that the stimulus should be something negative, the lack of something. When I turn to my neighbor, hand him the newspaper and ask him to read the head lines, I expect him, too, to respond to something negative. And I find that he can do it, can respond to the black letters. What we call black is physically the absence of light. Responding to lack of food is therefore no exceptional case. The details of physiological mechanics bringing about motion in a straight line when this stimulus acts on the animal, do not concern the psychologist especially. They may be studied in a suitable zoological textbook. All that we have to emphasize here is the fact that Nature has made animals so that lack of food, acting as a stimulus, brings about as a response to that stimulus .. locomotion in a straight line. This locomotion in (generally) a straight line is the most fundamental kind of animal behavior, universally applicable from the lowest species to the highest of the animal kingdom, to Man. We want to remember it as the most fundamental form of behavior. Gradually we shall add to it an ever increasing list of further forms of behavior serving the ever growing needs of the organism in its evolution.

Having introduced in the last paragraph the concept of a "stimulus," we must have a clear conception of what is meant thereby. There are many different kinds of things of a physical or chemical nature which may act on the body in such a manner that a chemical change results in the body; and anything that is capable of doing this may be called a

stimulus. A candle which illuminates, a violin which sounds, a brick which presses on the skin, influences of all kinds capable of mechanically or chemically tearing, dissolving the living tissue, such as cutting knives, tearing saw blades, burning acids, also volatile substances like camphor, cheese, perfume, substances soluble in our mouth like sugar, salt, alum, temperatures of a substance (gaseous, liquid or solid) in contact with the body which are higher than the temperatures of the body tissues, temperatures which are lower than the temperatures of the body tissues, even electrical currents and the increase or decrease of an electrical current, these and many other substances or conditions of substances may be called stimuli when they have a chance to bring about in the body of an animal or a plant a chemical change. It is evident that the meaning of the word stimulus is far extended over its original meaning which is that of a pointed stick used by the ancient Romans (and still used by the inhabitants of certain countries) to drive their draft animals, their oxen.

We have also introduced the concept of a "response." The response is the effect of a stimulus, but not its direct effect. The direct effect of the stimulus is the chemical change, a change of the usual chemical constitution of the tissue affected into another and less usual one. This change we shall always in this book call the "excitation."

The excitation in turn calls forth what we shall name the "response." There are two chief kinds of responses. In contractile tissue, in muscles, contraction may occur; and in secretory tissue, in glands, secretion. The latter is of considerably less interest to the psychologist than the former, because of its limited social significance. Of still less interest, for the same reason, are such rarer forms of animal responsiveness as the electric strokes of animals like the

electric eel or the ray. Let us remember, then, that nearly always for us the effect of a stimulus is an excitation and the effect of this in turn is contraction. Whenever we choose to speak only of stimulus and response, we omit the intermediate link, the excitation. We may, of course, leave it unmentioned where it is unnecessary to mention it, but we must not forget that without the excitation the stimulus, directly, does not produce any response.

In the usage of language we often substitute, for brevity's sake, a simple noun for a whole sentence. In order to refer by a simple noun to the fact "that living tissues are capable of undergoing a rapid and pronounced chemical change when acted upon by a stimulus," we shall in this book use the abstract term "sensitivity." The corresponding adjective is sensitive.

In higher animals we find differentiated sensitive tissue. The meaning of "differentiated" is easily understood. In the very lowest animals every part of the body has the same properties as every other. Every part is equally sensitive, for example. In the higher animals, however, certain parts of the body are so much more sensitive than others that we give them the special name of sensitive tissue. Let us illustrate the distinction. Sunlight falling upon our hand produces there very little effect, and even this only very slowly. It takes days or weeks before we can notice that the skin darkens. The skin is very slightly sensitive to light. The same light falling upon the retina of the eye for only a hundredth of a second produces there a profound chemical change. When a part of the body has assumed one among the properties which all living tissues possess, for example sensitivity, to such a degree that we almost forget that it has those other properties too, altho but weakly, we say that it has become differentiated.

That we call the body material "tissue" is due to the purely fortuitous fact that, when living bodies were first examined under the microscope, they seemed somewhat to resemble "woven material," the meaning of the French word tissue.

The changing of undifferentiated tissue into sensitive tissue is naturally only one of several forms of differentiation. Among those properties of the undifferentiated tissue which especially interest us we find, in addition to sensitivity, contractility and conductivity.

All tissues are contractile, but only when they are so differentiated that they possess a high degree of contractility are they called contractile.

All tissues are capable of conducting an excitation from a point anywhere within the tissue thruout the whole tissue; but only when there is a high degree of conductivity (or, using a physical term that means the same, a "low" degree of "resistance" to the flow of the excitation) is the name "conductive" applied. One must not think of conductivity, in this chemical sense, as something mysterious. We may well think of it as something comparable to the conduction of a drop of syrup, of sugar, thruout the contents of a tumbler of water or of tea. We have all seen the sugar, in such a case, spread thru the water like a cloud.

What would you ask for if sent to a butcher shop in order to bring home samples of sensitive, of contractile and of conductive tissue?—You might ask for an eye ball or a piece of the skin of the tongue in order to have sensitive tissue. Not the whole eye ball is differentiated sensitive tissue, of course. But the inner lining of the back wall, the retina, is tissue extremely sensitive to light. The taste buds on the tongue, further, are very sensitive to certain chemical substances, like sugar, salt, quinine, when these are placed

upon them in solution. Differentiation, after having separated sensitive from other tissues, proceeds and separates tissue sensitive to light from that sensitive to chemical solutions, to sound, to warmth, to cold, and so forth.

When asking the butcher for a sample of contractile tissue you would simply ask for meat. Our muscles are our differentiated contractile tissue. When asking for conductive tissue, you would ask for brains. All the nervous tissue of an animal is differentiated conductive tissue; but the only nervous tissue which the butcher has handy for you, is the bulky mass of nervous tissue contained in the cranial cavity. Elsewhere in the body it appears only in small pieces not easily handled for commercial purposes.

We have previously warned against using such phrases as hungry in the explanation of an animal's behavior. We have before-hand decided to reject all terms that have a subjective meaning, that refer to consciousness. We are studying the Other-One in preference to Our-Selves. For the same reason we avoid here, in speaking of sense organs (that is, sensitive organs), the use of the term sensations. It is far better to use the term excitations, which has no subjective meaning. Speaking later in detail of the functions of the several senses, again it will not be advisable to speak of such sensations as green, red, and so on. It is much clearer to use the unambiguous and purely objective term and speak of the specific excitation green, and so on.

In animals made up of differentiated tissues the excitation obviously cannot serve its purpose, of causing contraction in contractile tissue, without first being conducted from the sensitive tissue, where it originated in consequence of stimulation, to the contractile tissue that is to act, by contracting, as a motor of the body. It is only to be expected, then, that the elements or neurons (the "cells" in the strictest terminol-

ogy of biology, not in the loose sense in which biology still speaks of a "nerve cell") making up the conducting organ, the nervous system, should appear in the shape of long and thin threads, microscopical, but of proportions comparable to those of telephone wires. The reason why they should have this shape are exactly the same, too evident to require enumeration, which give this shape to the conductors of a telephone or telegraph system.

These conducting threads, strings, fibers, or whatever we call them, of the living body, under the microscope reveal to the eye several additional features. We shall discuss them here, not so much because the psychologist must under any and all circumstances know them, but rather because the present beginner in psychology ought to be warned against believing that the knowledge of these additional details of the structure of neurons constitutes for him an important part of psychological knowledge.

Of great importance for the psychologist is a clear understanding of the principles ("specifications," so to speak) underlying the architectural plan in accordance with which the nervous system must have been built up by the Creator out of the building material. The neurons are this building material. These functional principles conditioning the architectural design will be discussed and often referred to in the following chapters of the book because of their great psychological significance.

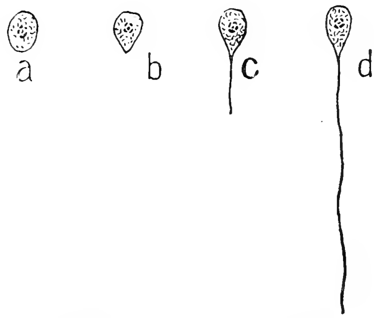
As a matter of fact, at the present time, the details of the building material itself, the mere structural details of individual neurons given in this introductory chapter, do not contribute anything essential to our (present) understanding of psychological problems, altho it is possible that new discoveries in the future may allow them to play such a role.

The smallest structural elements of which both animal and

vegetable organisms consist have for about a century been called "cells." This means literally boxes—we have a box under our house which we call a cellar. The name appears less strange to us on knowing that those structural elements which were first discovered by means of the microscope happened to look like little boxes. These were plant cells. It was, of course, soon found that not all vegetable elements of structure are box-like. Some, for example the long and thin flax fibers used for the manufacture of linen, do not resemble a box. But the name cell had already been adopted by the biologists as a general name for elements of structure and was now applied also to those elements to which it was not applicable in its literal meaning. It was equally applied to the elements of structure in the vegetable and animal kingdom, and the whole growing, living, world was—and is—said by the biologists to consist of cells. Accordingly the strings, which serve as conductors for excitations in the bodies of higher animals, ought to be called cells, too—perhaps nerve cells for the sake of distinguishing them from other kinds of cells. Such, however, is not the case. The term nerve cell has come to mean, unfortunately, something different. We shall at once see what and why.

In its most undeveloped form an individual unit of nervous tissue is a small, almost spherical body (compare figure, at *a*). As this body grows it becomes pointed in one or more places and sends out a string-like prolongation, which continues to increase in length (figure, at *b, c* and *d*), so that it may become easily a hundred thousand times as long as it is thick, reaching a total length of several feet, whereas its thickness is always microscopical. The original little ball from which the string grew out, continues then to exist as a relatively thick swelling of the string. We must remember, however, that it only looks thus, that it did not originate

as a swelling of the string. Being relatively bulky, it is not difficult to understand that this thickened part of the string should have attracted the interest of investigators before the exceedingly fine string. When it was first the



GROWTH OF A NEURON.

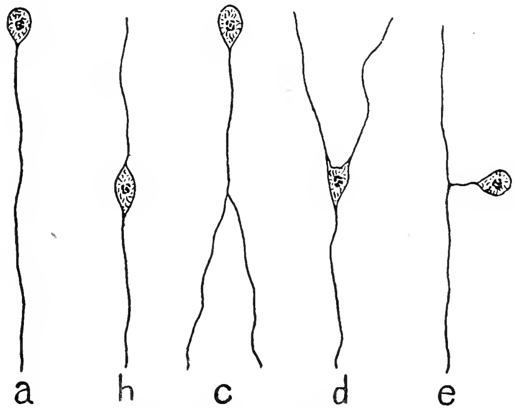
object of biological research, its belonging, as a part, to the long and fine fiber was quite overlooked. It was studied as an individual thing, and the name cell, generally applied to the elements of biological structure, was applied, instead of to the whole fiber with its swelling, to the swelling alone, which was called a nerve cell. So the inconsistent use of the word cell in its application to nervous tissue, referred to above, came about and is still almost universal.

Since about 1890 a new, unambiguous terminology has come into use, which we adopt. We call the whole structure, the fiber with its swelling, a neuron, the fiber without its swelling simply fiber or string, and the swelling alone a ganglion cell. Ganglion cell and nerve cell mean the same.

The use of the word ganglion cell is explained thus: In nervous tissues gray looking masses are frequent which, on microscopical examination, reveal themselves as accumulations of swellings carrying with them, naturally, the contiguous pieces of their fibers. It is as if we had a large number of ropes each having a knot somewhere and had

taken all these knots in one of our hands. Such a mass of nervous tissue has long been called a ganglion. Now, it is a peculiar biological fact that these swellings of neurons are not found simply here and there in isolation, but that they are always found in groups, sometimes not very large, sometimes very bulky—these very ganglions. Since the swellings of the neurons are found only in ganglions, they have been given the name of ganglion cells in addition to the name of nerve cells.

Many are the forms in which the neurons present themselves. Our next figure shows an assortment of them. The

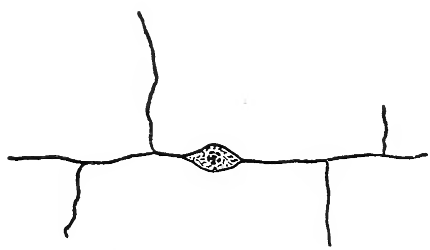


TYPES OF NEURONS.

swelling may be at one of the ends as in the case of *a* and *c* of the figure, or away from either end as in the case of *b, d,* and *e*. The long fiber may split into two fibers as in *c,* or even into more. The swelling may happen to occur just at the point of division of the string. In this case the neuron looks like *d*. The string may in its course turn sideways, form a kind of loop, and continue from the turning point in the original direction. If now the swelling happens to be at the place of the loop, the neuron must look like *c*. In all these varieties of form we find the same structure, a

string with a swelling. Some years ago, when the interest of the histologists was still in the main restricted to the ganglion cell, various kinds of such cells used to be distinguished according to the number of long fibers which they appeared to send out, and called unipolar (*a*), bipolar (*b*) and multipolar (*d*) cells. Since the ganglion cell has ceased to be regarded as an element of structure in the earlier sense, these distinctions and names have practically lost their significance. The neuron is essentially a string capable of conducting an excitation from one end to the other. All its structural and functional properties are necessarily subservient to this end, to conduction.

Certain features of the neurons, which have not yet been shown in our figures, should still be mentioned. We said

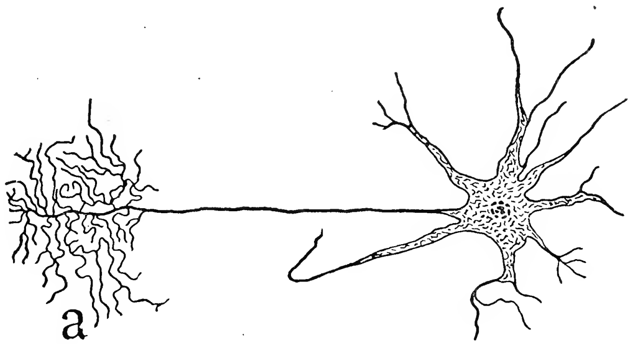


COLLATERALS.

that the long fibers sometimes split into two fibers. Another breaking up of a fiber may occur in a manner similar to the way in which a river takes up large tributaries, forming approximately right angles. Such tributaries of a neuron are called collaterals.

Still another feature of the neurons is to be mentioned. Each ending of a nervous string looks somewhat like the frayed-out end of a thread. The end breaks up into a large number of relatively ˙ort branches, the so-called terminal arborization (in the figure of a ganglion cell at *a*). In case the swelling of the neuron happens to be located at one of

the ends of a neuron, these small branches must naturally come out of the swelling itself. This end brush directly proceeding from the swelling is said to consist of dendrites, which is a Greek name meaning about the same as the Latin

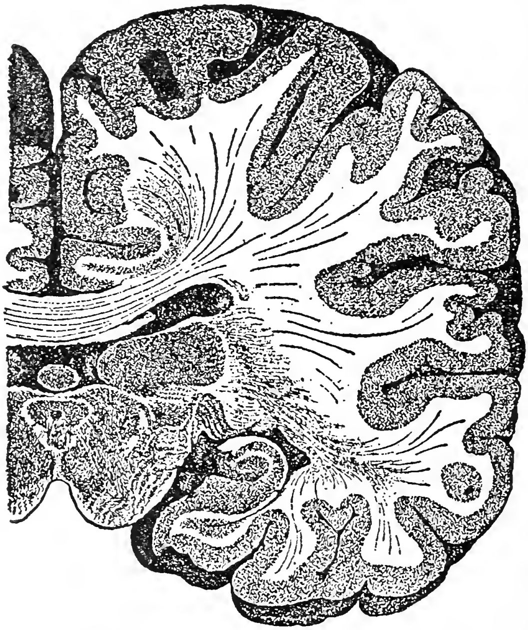


GANGLION CELL.

name terminal arborization, that is, tree-like branchings. In the figure of a ganglion cell a neuron is represented whose main fiber is relatively short, almost shorter than the dendrites. This shortness, however, is not the rule, but rather the exception. The main fiber, often also called axis cylinder, usually greatly exceeds the dendrites in length.

There is frequently a difference in coloring between the parts of a neuron. The ganglion cell looks dark, the fibers lighter. This has given rise to the distinction of white and gray matter in the brain—gray matter taking its name from the presence of numerous dark ganglion cells among the fibers. In the brain there seems to be a peculiar advantage—not yet perfectly understood—in having the gray matter spread out over the surface, the cortex, in as thin a layer as possible. To this end the surface is much increased by the formation of large folds, separated by deep fissures, as seen in the figure of the frontal section of the right cerebral hemisphere. The surface of the brain is estimated to be equal to a square with a side eighteen inches long With-

out the fissures the surface would be only about one-third of this. The mixture of ganglion cells and fibers making up the gray matter is illustrated by the three figures show-



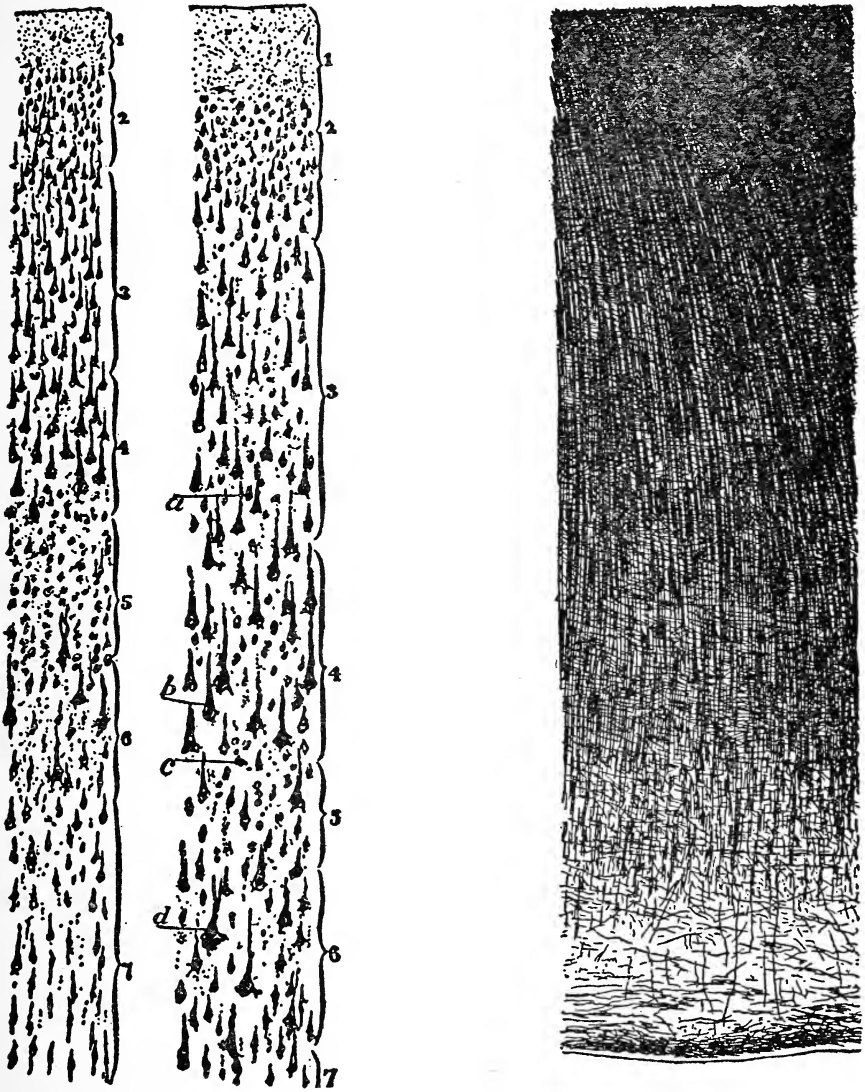
FRONTAL SECTION OF THE RIGHT CEREBRAL HEMISPHERE.

ing in microscopical enlargement sections of the cerebral cortex, stained either so that only the ganglion cells are visible or so that only the fibers are visible. Actually both are present in the same piece of gray matter. The popular idea that the gray matter is of greater importance than the white matter, is of course a superstition.

The ganglion cells have a delicate interior structure, and even the fibers are not simple, but possess an interior structure, so that they may be said to consist of fibrils. About the functional significance of these inner divisions of a neuron too little is at present definitely known.

The question as to the function of the ganglion cell and the function of the fibrous parts of the neuron is answered

at present in a manner very different from that which was customary fifty years ago. It was then often asserted that



SECTIONS OF THE CEREBRAL CORTEX.
Ganglion cells stained. Fibers alone stained.

the ganglion cells were the residences of ideas, each little box the seat of one idea, so that the total mental capacity

of a person might be determined by counting the number of his ganglion cells. Men of science nowadays recognize that an idea, something subjective, spiritual, mental, cannot be said to be seated anywhere. The ganglion cells do not have any more direct and more important relation to the Other-One's life than that of the conducting strings. On the contrary, we shall in the following chapters see that we can fairly well understand the Other-One's life without making any reference to his ganglion cells. Their physiological significance is probably, in the main, only of the following two-fold kind.

The ganglion cell is the point of vegetation in the neuron, so to speak, from which all growth proceeds; and it is the storehouse from which the neuron in any emergency can quickly draw the means of subsistence. Let us elaborate this statement.

We have seen that the whole string of a neuron grows from a little sphere. This sphere continues to exist even after the neuron with all its ramifications has obtained its full development, and is then the ganglion cell of the neuron. If growth is necessary later, say, because a branch of the neuron has been cut off or otherwise destroyed, new growth proceeds from that point of the string which is farthest from, but still connected with, the ganglion cell.—On the other hand, if a conducting string is continually used for hours, changes in the appearance of its ganglion cell occur which probably indicate changes of a chemical nature, called by the physiologists signs of fatigue. It seems that the string, in order to serve continuously for a long time as conductor of an excitation, needs to be resupplied with certain chemicals, and that these chemicals are kept in store for the string within the ganglion cell, which, because of its size, is less quickly exhausted than the string. Whether the

ganglion cell has any significance in addition to those functions which have just been mentioned, seems doubtful.

Let us recall, now, what we said to be the most fundamental of the many diverse forms of animal behavior. Every animal, we said, is by Nature so made that lack of food, acting as a stimulus, brings about as a response locomotion in a straight line. We have to add to this behavior a second form, which is of equally fundamental importance. An animal, in its forward march, is likely to meet an obstacle, for instance, a piece of rock, or a tree, or whatever may be heavy enough so that the weight of the animal would not suffice to push it aside. Unless the animal had a locomotor ability beyond that of moving in a straight line, such an obstacle would forever stop it, would cause its early death by starvation.

Nature therefore has given every animal a second form of behavior, that of avoiding the obstacle by changing its own position, its direction, in front of an obstacle, so that, when further proceeding in a straight line, it would leave the opposing object at the side of its path. It is decidedly worth while to study in detail a very simple mechanism capable of changing the direction of an animal in front of an obstacle, because we learn thus how exceedingly simple such a mechanism may be, and how unwarranted would be assumptions of mysterious properties of animals, of "vital forces" and the like, assumptions toward which we are all too inclined because of the poetical rather than scientific way of thinking of the mass of human society of which we are a part.

CHAPTER II

The Other-One manifests Machine-like Reactions.

Let us imagine a lump of living tissue having the shape of a snail. Let us for simplicity's sake call it a snail. Let us examine and answer the question if this animal could "live," in the sense in which the Other-One lives, however remote the resemblance of their lives may be. The animal we are imagining is still a little simpler than a real snail. Our snail has no house (not all snails have a house), no tentacles, no nervous system, no differentiated tissue whatsoever so far as it concerns us. It is simply a lump of undifferentiated tissue of the shape of a snail. But it has a mechanism driving it forward in a straight line in response to the stimulus of lack of food. The details of this mechanism, however, do not interest us at all.

When placed on a pane of glass and observed only with respect to its silhouette, the picture of this imaginary snail is as simple as the outline given in our figure. What happens now, if the snail is gently touched, say, at the front end in the place marked in the figure? Owing to its sensitivity, the tissue touched undergoes a chemical change. We say that it becomes excited. Being contractile, the tissue reacts to its state of excitation by contracting. All the tissue of the right side of the head becomes immediately concentrated, condensed, into the space shaded in the figure. The head assumes an unsymmetrical form like the one shown in the figure.

The excitation, first caused only in the neighborhood of the point touched, spreads now in consequence of the con-

ductivity of the tissues. It spreads slowly thruout the whole body. Even after having reached the most remote part, the excitation continues in motion, continues to distribute itself. It becomes weaker in the part where it originated, stronger in the remote parts, until its strength has become the same everywhere, until the chemical constitution of the body, different in different places just after the stimulus was applied, again is uniform all thru the body.

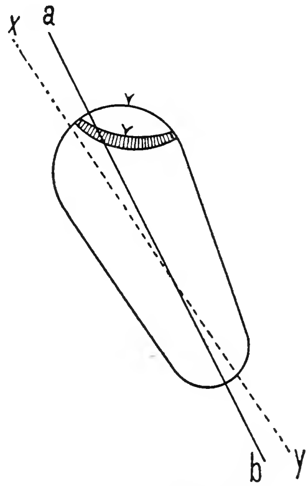
Wherever the excitation reaches in its movement thru the body, contraction of the tissues occurs. On the other hand, in the region where the excitation originated and where it now weakens, that is, in the shaded space of the figure, the original contraction weakens.

We must understand that we are imagining our snail to be sponge-like. We suppose that contraction in a part of this sponge, since the material is made to occupy less volume when contracted, makes that part denser in a physical sense. This implies a greater weight per volume unit. The tissues become now gradually denser, heavier, in the remoter parts and simultaneously less dense from moment to moment in the region where the stimulation occurred, in the shaded space.

This change of the density of the tissues, however, accompanying the gradual spreading of the excitation, is itself gradual, not sudden, and thus does not produce any further deformation of the body surface, of the animal's shape, like that which followed the sudden application of the stimulus. After a second or two, we find the body with a weak uniform excitation, with a weak uniform contraction, and still with the deformation of the surface at the place where the stimulus was applied.

Now, the chemical state which we have called excitation, means the presence, in the tissues, of chemical substances

which are not ordinarily there. They must not remain there. A case of illness is an analogy. If we are sick, have



SNAIL TURNING.

a fever, this also means the presence in our body of chemical conditions, chemical substances, which are not normally there. If they remain, our life gradually weakens and finally ceases. When we recover, this means that these abnormal substances are being removed from the body, that the normal chemical constitution is being restored by those forces which are always active in living matter, whose study makes up the branch of science called physiological chemistry.

In our snail now, too, the normal chemical constitution of the body gradually returns. As it returns, the state of contraction gradually disappears. The body slowly expands again. It expands like a wrinkled football which we blow up. It expands most where it was indented, where the surface offers least resistance. But it also expands everywhere else. The assumption is entirely justified that our snail, too, in expanding loses its wrinkles, so to speak.

The deformation disappears. But at the same time, since the tissues are now everywhere slightly and uniformly condensed, the effect of the expansion shows everywhere on the surface of the body. The expansion shows also on that side of the head which was not stimulated. This brings with it a change of the situation of the axis of the body.

Think of the axis (*ab*) in our figure as if it were a knife edge on which the body could be balanced at the start. There was then as much weight of the body on one side of the solid line as on the other. At a later moment, some time after the deformation, when the excitation and the disturbed tissue density have already become uniform thruout the deformed body, the animal could no longer be balanced on this knife edge. It would become necessary to shift the knife edge into a new position (say, *xy*), the dotted line, in order to keep the deformed body now balanced on it. The weight axis, now, of the deformed, but uniformly dense, body is the dotted line.

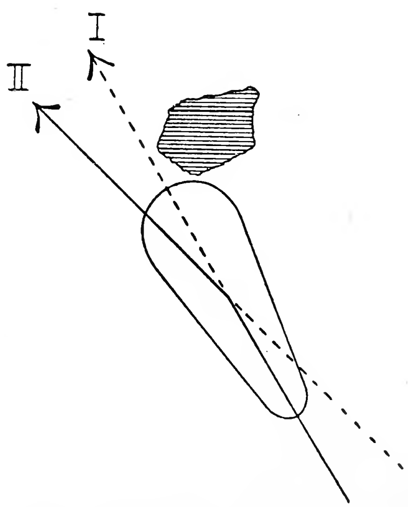
But the very gradual expansion, which accompanies the disappearance of the excitation from the entire body,—this redistribution of normal density and weight—occurs in a body which is already uniformly dense. The weight distribution on the two sides of the knife edge (*xy*) is therefore not appreciably disturbed relative to this knife edge. The second position of the knife edge on the ground therefore becomes (approximately) the axis of the body restored to its normality perfect in shape and otherwise, as it was before the stimulation.

Only one change remains as the consequence of the stimulation. What remains is a change of the situation of the animal. The part of the animal which was touched is now somewhat removed, sidewise, from the point in space where the contact occurred. The axis of the animal is farther re-

moved from the point of the stimulus than it was when the stimulus was applied. The front end of the axis points in a somewhat different direction. The animal faces a different direction. It is the same as if the mere contact had been an externally applied forceful push.

The fact just mentioned may reveal an importance quite out of proportion to its simplicity. Apply it to the problem of getting an understanding of the role played in animal life by the nervous system. There was no nervous system in our "snail." We, unfortunately and customarily, look upon our "brain,"—better, our nervous system,—with a peculiar awe. We think of its function as being the very essence of life. We have to learn to think of it in a very different, far more modest manner, if we desire to possess a sane, well proportioned view of animal life.

The snail whose life we are discussing, needs no nervous system in order to live. Suppose the snail is creeping on the



SNAIL AVOIDING AN OBSTACLE.

ground in the direction of the arrow I in our figure. We agreed to take the mechanics of locomotion in the forward

direction for granted. We may then at once devote ourselves to the more special problem. The snail, creeping forward, approaches the stone which accidentally lies in its way, and the right side of its head comes into contact with the stone. We know now, from our previous discussion, what must happen. The part which has been excited by the touch of the stone, contracts. A little later, expansion of the body occurs, but the expansion not only of the part near the stone but of all the body with practical uniformity. The result is a change of position. The axis of the snail now assumes a position more nearly that of the arrow II.

The internal mechanism which caused the original forward movement, again becomes effective. The snail, moving forward, perhaps again comes into contact with the stone. The same happens as before. The axis turns a little farther toward the left. Again the forward movement begins and now, perhaps, is continued without touching the stone; the actual path being approximately that indicated by the broken solid line composed of parts of I and II.

It may be advisable to call attention to the fact that such an animal does not do what a human being might indeed do: avoid the obstacle by "going around it." Such a simple organism merely changes its direction and immediately proceeds in a new direction.

What we have described is by no means an extraordinary event in the animal's life, an unusual kind of behavior. It is practically the complete story of the snail. The snail, in order to live, must eat. Lack of food, continued for some time, results in chemical changes in the body. In consequence of structural and functional properties of the body which we cannot study here, these chemical changes bring about a forward movement. A rock (or any other obstacle) lies in the way. If the rock could permanently stop the for-

ward movement, the snail would starve to death. But, in one or several stages, a change of the situation is brought about by a change of the direction of the animal's axis. Now the snail creeps on. Other obstacles which may be encountered are taken in the same way. On its forward march the snail, by accident, sometime passes over edible substances, which stimulate the mouth organs and, consequently, are consumed. Later, lack of food brings about locomotion again, and the same things happen in the same cycle.

One may feel inclined to exclaim: An animal's life cannot be so simple, so automatic as that,—dependent on the mere accident that food substances should be in its fortuitous path! But why not? It is true, many a snail will fail to come across any food substances and die of starvation. Such is life! But enough will have better luck and live to propagate the species, for food adapted to the needs of snails is common on earth.

Not only food is obtained in this—if one wishes to call it by that name, "mechanical"—way; protection against injury is thus made possible too. If the snail, instead of approaching a rock, had come near a directly injurious substance, it might have changed its route even before touching that substance; for the tissues of its body are excited, not only by touch, but also by many other influences, for example by a change of temperature, or by the effect of a volatile chemical substance. A piece of camphor instead of a rock would have turned the snail some distance before touch would have been possible.

Another important method of protecting itself is that of completely retiring within its shell, if the animal has one. This again requires no additional mechanism. We silently presupposed above, that the touch of which we spoke was

a very gentle touch. It will, of course, always be gentle if it results from the snail's—this slowly moving animal's—own motion. If the touch is relatively strong, as when a child touches a snail with a straw, the excitation resulting and spreading with great force all thru the tissues must cause, not only the tissues at the point of contact, but in quick succession also the neighboring tissues, possibly all of the body, to contract vigorously. If the whole body contracts strongly, it must, since a part of it is attached to the interior of the shell, necessarily disappear in the shell.

A somewhat sophisticated student, nevertheless, was dissatisfied with this description of the animal's life. What will happen, he asked, if the stone against which the animal moves, happens to touch it in the very center, neither to the right nor to the left? Does this situation not require a mysterious vital force, a will, or whatever you prefer to call it, capable of turning it away from the obstacle?

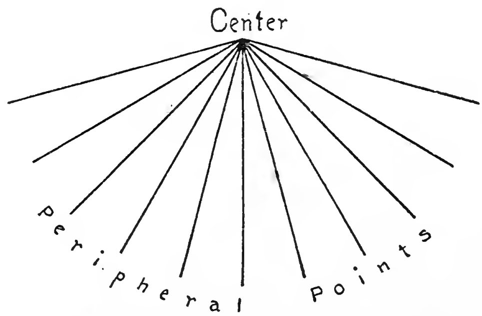
Similar problems were quite the fashion in the class rooms of the philosophers of the middle ages. If you place a donkey between two bundles of hay, they argued, equally large and equally sweet smelling, he is unable to move in either direction and must starve to death, unless he has a mysterious power, such as a will. Any farmer, however, no matter whether he believes in a free will or in determination by natural causation, knows better. He knows that it is impossible to make two bundles of hay exactly alike. Only a miracle could bring that about. And if they were alike, the slightest motion of the air would cause the one nostril of the animal to get more of the aroma of the hay than the other, and the animal would turn. So it is here.

The animal is affected by many forces other than those which we are studying here. For example, it moves on rough ground. The fore end of its body is not shaped

exactly like the rear end. Being moved back over the rough ground in consequence of a touch at the very center of the front, and crawling forward again, the animal could only by a miracle touch the stone a second time with its very center. But if the touch occurs only slightly to the right or to the left, the next touch will occur still more to one side, as we have seen; and the animal will soon move on, leaving the obstacle sidewise.

A thoughtful and generous student of our book here interrupts us: "We have convinced ourselves," he says, "that our imaginary snail, consisting of undifferentiated tissue, does not need a nervous system in order that it may live. Nevertheless,—why should the Creator be so stingy? Does he not give us many things which are not absolutely necessary? He might have offered the snails which populate the gardens and forests a nervous system as a mere luxury!"

The conducting strings, the neurons, we have learned, are the elements of which a nervous system is made up. Suppose now, the Creator had appointed us to act as his deputy, to construct a nervous system and to offer it to our nerveless snail. Having a vague idea that a nervous system in an animal is something like the telephone system of a town, we would probably unite a considerable number of conducting strings in a central point, like our figure called "An impos-



AN IMPOSSIBLE NERVOUS SYSTEM.

sible nervous system." Altho the snail can get along without a nervous system, why should it not get along even better when in possession of our gift!

Imagine the snail has accepted the gift and is approaching the obstacle, the rock which we showed in our figure. The moment when the contact occurs one of the peripheral ends of the nervous strings is excited. The strings are so differentiated that they have an immensely greater conductivity, that is, lesser resistance, than the undifferentiated tissues. The excitation, therefore, is conducted to the point where all the nervous strings are connected and thence with great intensity of flux along all the nervous strings, thus reaching effectively all the parts of the body. Consequently, all the parts of the body contract practically at the same time with great force. A prompt and relatively strong contraction at the point of stimulation, followed slowly (as previously described) by a weak and uniform contraction of the whole body is no longer possible. The resulting change of position is also impossible.

The body in its entirety contracts and, after awhile, expands again, to touch the rock, of course, in exactly the same way that it did the first time. In consequence of the touch, the whole body contracts again. It expands again, contracts again, expands again, contracts again, and so on endlessly, or rather until the animal is either exhausted or starved or both. Any way of avoiding the obstacle is impossible.

It is clear, then, that the snail would be very much worse off with this kind of a nervous system than without any. Without any nervous system it can live quite well, unless it happens to have exceedingly bad luck. With this nervous system it cannot live any more than a human being could live who, whenever he saw or heard anything, instead of

normally responding to the situation presented, would invariably have an epileptic fit, a violent and entirely useless, too widely spread, unadapted, muscular contraction.

If our snail is wise, it thanks us for our kind intention but begs us to keep our gift. Of course, all that we have proved is that this particular nervous system is unacceptable. Another kind, differently constructed, might be an acceptable gift.

One case in which a nervous system could be serviceable in an animal's body would be that in which the contraction is to occur not at all at the point of stimulation, but at some other point. This result can be brought about by conducting away the excitation from the point of stimulation by string-like tissues which cannot themselves contract, but possess a greater conductivity than ordinary, undifferentiated tissues. Carried to another point, the excitation can there perform its normal action, that of causing the contraction desired at that point.

This kind of function is necessary in all the more highly organized animals, in the insects as well as in the vertebrates. As example we may use one of the most familar insects, a moth. Everybody knows the striking behavior of a moth, its flying towards any source of light. It is the result of the nervous connections between the wing muscles and the eyes. The right eye is connected (if not exclusively, at least better) by nervous strings with the muscles of the left wing, the left eye with the muscles of the right wing. If the moth has the source of light on its right side, the right eye receives more light and consequently a stronger excitation than the left eye. The left wing then beats the air more forcefully than the right wing, and the animal is turned to the right until both eyes are excited by the light with equal intensity; that is, until the moth flies directly towards the light.

An inquisitive student here puts before us a question. "Is this behavior of the moth of any value to it?" We answer that it probably is. It may be that the moth is thus aided in getting to places where food is obtainable. It is true that millions of moths are destroyed thru this instinctive action of flying toward the light. Sources of light destructive to moths on the surface of the earth are an invention of mankind, rather recent, for which Nature cannot be expected to have made provision in giving the moth its biological inheritance.

So much is plain, that it could do a moth, whose anatomical structure is (relatively) so highly developed, no good whatsoever if an excitation caused by light in the region of the head would cause a contraction of the tissues there, in the head. In order to be of any value to the animal it is necessary that the chief sensory areas, the eyes, and the chief motor organs, the wing muscles, be connected with each other by differentiated tissues of the conducting kind, by nerves.

(The student who has but little biological knowledge must, and might here at this moment, be warned against confusing the terms "connective tissue" and "conductive tissue." The former refers to an entirely different kind of tissue with which this book is not concerned. "Conductive tissue" does not connect by binding things mechanically together, but "connects" only by conduction.)

Will it side-track us if we discuss here briefly another fact which is of great significance for the behavior of animals? We said that the movement of the moth's wings was caused by the excitation which comes from the eye. The question may be asked how a continous excitation like that in the moth's eye can cause a discontinuous rhythmical, movement like that of flapping wings. We have no need to

explain this here in detail, but it is important to point out, that such a transformation of something continuous into something discontinuous is an exceedingly common occurrence in nature. It is especially important to note that it occurs in the inorganic world, the dead part of nature, as frequently as in the organic world, in living nature, so that we cannot be accused of having neglected the possible claims for recognition of any so-called vital or mental forces when we simply stated that the wings flapped merely because of light falling steadily on the animal's eye.

The inorganic world offers many examples. The wind passing steadily over the surface of the ocean does not cause, by friction, a mere motion of the surface water in the same direction. It causes, as we all know, a motion of the particles of water mostly in a vertical direction, up and down, causing waves, which periodically rise and fall a considerable height. Or, when we blow a whistle steadily, the result is a rhythmical movement of the particles of air enclosed in the whistle, a sound in the physical sense. When water flows very slowly from the kitchen faucet, it does not fall in a continuous and very narrow stream, but in periodical drops. Air blown under water thru a tube, similarly rises in periodical bubbles. Nobody thinks that such a transformation in these cases requires any hypothetical vital or mental forces. To assume any such forces in the case of muscular activity is equally unnecessary. What we have said about nervous excitation in the eye causing rhythmical motion of the wings is all that need be said, unless we are specially interested in the details of physiological science.

After this deviation we return to our problem of psychology. What kind of a nervous system could be regarded as an acceptable gift by our snail,—or by any other animal?

We saw that one kind of behavior is impossible to the snail or any other animal lacking a nervous system, namely, a contraction at one point of the body in response to an excitation started at a different point, without any contraction occurring at this latter point. If the tip of one of the tentacles of a snail—let us think of a snail with tentacles—is affected by a certain stimulus, say, the heat of fire, it would undoubtedly be safer for the animal to move back by means of its locomotor organs, however far these are from the point of stimulation, than to respond strongly by a contraction of the stimulated tentacle and only weakly or not at all by action of the locomotor organs.

We see at once the close connection between the existence of a nervous system and of highly developed special organs, especially of locomotor organs. Higher animals, having legs, must indeed, because they have these special organs, respond to stimuli occurring at certain excitable points of the body, far from the legs, by pushing themselves forward or back on their legs, and perhaps by no other motor reaction. It would be strange indeed if, in order to put the legs in action, a stimulus had to be applied to the legs.

It is not necessary to illustrate this function of a nervous system by animal locomotion exclusively. Think of any other form of reaction. Think of a dog who scratches himself. Different motor organs (muscles) must move a leg to a different place according to whether the insect bites here or there. The snail, which has scarcely any specialized motor organs, just on this account does not absolutely need a nervous system. So much nervous tissue as a real snail possesses, serves minor purposes which do not much concern us here.

On the other hand, if an animal has specialized locomotor and other motor organs, fins, wings, or legs, with double

sets of muscles for forward and backward motion, its nervous system must be designed in accordance with the following plan and cannot be designed in any other way without defeating its purpose. Certain excitable points of the body must be connected by conducting strings with certain contractile tissues located in definite points of the body; other excitable points must be connected with certain other contractile tissues of the body.

If we simplify our way of expressing this we may say: *Each sensory* (that is, excitable) *point of the body must be connected by a conducting string with a definite motor* (that is, contractile) *point of the body.*

Remember, however, that the facts are not quite so simple as they are expressed in these words. Actually, a single sensory point is scarcely ever excited in isolation, and a single contractile point, a single muscle fiber, never contracts while all other fibers remain at rest. However, general statements of fundamental facts for the purpose of remembering and reflecting upon them in the abstract, are always artificially simplified. In this sense one can even say that such statements are not true. Nevertheless, otherwise they would be of little value to our thought, which at any moment is limited in capacity. The statements may not be true, but they are valuable to the seeker after truth.

All scientific laws, not excluding the greatest and most famous of them, are artificial simplifications. An illustration, even tho it be a deviation from psychology into methodology, may not be amiss. When Kepler, for example, discovered that the planets move in ellipses, he discovered something that is not true. No planet moves around the sun in an ellipse. Kepler's discovery consisted in an artificial but useful simplification of the facts of observation, in showing us that we can well afford to regard the orbits

as ellipses in spite of the fact that they are not strictly ellipses.

We must proceed in Psychology in the same way. And we shall in this book often proceed thus. Only by simplifying the facts (using good judgment therein) can we bring them within the limits of our thinking capacity.

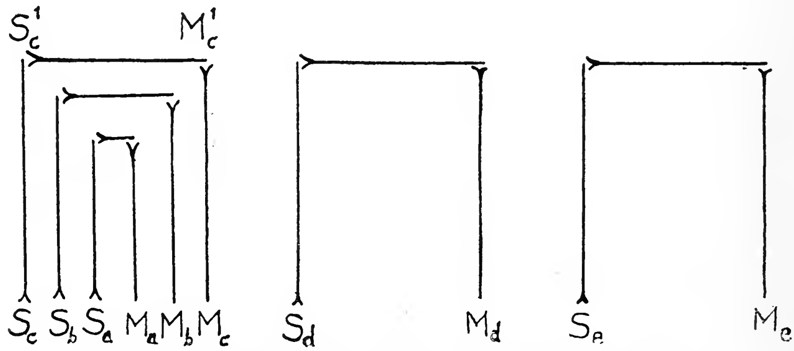
This justifies our speaking of the connection of one sensory point with one motor point as if such a simple nervous connection actually existed.

We may represent such nervous connections graphically, that is, in a perfectly arbitrary design selected only with reference to clearness and other conveniences, which become apparent at a later time. Each sensory point S in our figure is connected with one definite motor point M by a conductor, represented in the figure, of course, by a line. That this connecting line has the form of a flat arch, made up of three straight lines, is by no means essential. We shall gradually find that this form has special advantages which no other form will give us as well.

Abstractions make dull reading. The next paragraph is nothing but a statement, in very abstract terms, of the advantages to be derived by representing a nervous connection by an arch consisting of three straight lines. Those who dislike dull reading, will omit the next paragraph and pass on to the following.

Any graphical representation of such a qualitative fact as that of a functional connection between two parts of a living body is an important means of describing the qualitative fact in quantitative terms. In this manner a possibility is opened for the development of a scientific theory. Scientific theories, scientific laws, are observed facts described in quantitative, that is, mathematical, terms. Mathematical descriptions are made either graphically (geometrically) or

analytically (arithmetically, algebraically). We have just shown a part of the method used in the graphical description. It uses a very definite terminology, so to speak. The "terms" are arches consisting of three straight lines each. We shall later see that this enables us to describe important nervous functions in arithmetical terms. And this quantitative method will enable us to draw conclusions as to the functions of the nervous system quite impossible if we had stated



NEURON ARCHES: DIAGRAMS OF REFLEX PATHS.

the facts in purely qualitative terms, as is usual in neurological discussions. However, we cannot anticipate these results here. We merely want to indicate that the graphical representation is to serve a very definite purpose.

Now let us speak again in the concrete. Each of those straight lines means a neuron. Each of these arches consists of three neurons. We may place the arches in our graph side by side like $S_c M_c$ and $S_d M_d$ and $S_e M_e$. Or they may be drawn nested like $S_c M_c$, $S_b M_b$ and $S_a M_a$. Which form we choose depends purely on which form offers the greater convenience and clearness in describing whatever we wish to describe.

We must never think of the length of any of these lines, but only of their number. It is the number which represents the total length of the conductor. In the form where the

arches are nested, we do not think of them as differing in size. On the contrary we think of them as being all exactly the same kind of arches, drawing them of different sizes only in order that we may see them in separation and without confusion. We shall see later that the size of any arch, the length of any of its lines, will play no role in our calculations of the intensity and direction of function. Only the number, irrespective of the length, of these lines will enter into our calculations.

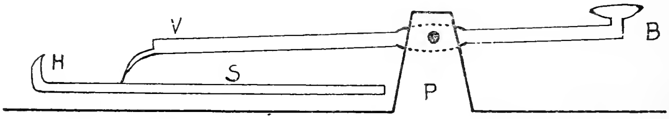
The function of one of these nervous paths just represented by arches, from S to M, is customarily called a reflex function. The choice of the word "reflex" is due to the historical accident that several hundred years ago this function seemed to the physiologists of that time to be somewhat comparable to the reflection of light from a mirror,—namely, in promptitude.

When we look at ourselves in a mirror, we do not have to wait any appreciable time before our image appears. It is reflected back at once. Neither do we have to wait long before a person upon whose toe we stepped begins to pull away his foot. On the other hand, we may have to wait a considerable time before the same person puts his hand in his pocket and draws out some money, after we have asked him to lend us a dollar, or ten, or a hundred.

Human actions seem to classify themselves naturally into two groups, those which are slow, hesitating, and those which are quick as the reflection of our image in the looking glass. The latter kind the early physiologists called reflex actions; and we still call them so, altho we nowadays have instruments which enable us to measure even the shortest time intervening between the stimulus and the response (the reaction time) and know that this length of time is rarely less than a tenth of a second, incomparably longer

than the time occupied by the reflecting of the light rays from the mirror.

One of the simplest methods of measuring the reaction time is by the use of the instrument of which the essential parts are sketched in our figure. A metal post, P, bears a lever of which one end has a button for the subject's finger. The other end of the lever is flexible, is a steel spring capable of vibrating horizontally at the rate of a hundred times per



MEASURING THE REACTION TIME.

second. This vibrator, V, has a point which writes on a smoked slide, S. H is a hook by means of which the experimenter pulls the slide. A pin not shown in the figure, fastened to the slide, holds the vibrator bent sideways until it is withdrawn. At the moment of pulling H, the vibrator begins to make a sound and to write every hundredth of a second one wave on the moving slide. As soon as the sound acts on the ear, the excitation runs to the arm muscle, the button is pressed down, the vibrator rises and ceases to write. And the number of waves written on the smoked slide is the reaction time, generally between ten and twenty, in hundredths of a second.

A reflex function is made possible by the existence in the body of the animal of a reflex path, a chain of neurons connecting a definite sensory point with a definite motor point.

The remarks following this paragraph will not interest all readers and may be passed over. We cling to these terms "sensory" and "motor" points, altho others would

prefer the terms "receptor" and "effector." As we have previously mentioned, the effects of excitations are contractions in the striped (skeletal) and smooth (organic) muscles and secretions in the glands. But the skeletal muscles, being the chief motors of the body, have more social importance than the other muscles and the glands. Secretions, compared with motions, have but little social significance and therefore interest the psychologist much less than the physiologist. In our figures the letters S and M (Sensory and Motor functions, Sense organs and Muscles) have for the psychologist a better suggestiveness than the letters R and E would have,—in all languages. For similar reasons we shall later speak of sensory and motor neurons rather than of afferent and efferent neurons. There are two further reasons for avoiding the words afferent and efferent. They are difficult to distinguish in the spoken language, in the class room. And they suggest to the student the very unfortunate conception of the brain as a reservoir or storage tank of something.

We do not know what the number of neurons is which, in the higher animals, make up reflex paths. It is quite arbitrary that in our graph we represent this number by three. There is, however, a certain probability that the actual number is often three and never less than three. In one of our arches, which, since they represent reflex functions, might well be called "reflex arches," for example in the reflex arch $S_c S_c^1 M_c^1 M_c$, the conductor $S_c S_c^1$ will for obvious reasons be called a sensory neuron, $M_c^1 M_c$ a motor neuron. The neuron $S_c^1 M_c^1$ will be called a nerve center.

No particular meaning attaches to the word "center" in neurological usage. It has like so many other terms a purely accidental historical origin. There was a time when even

scientists believed that certain parts of the nervous system, of the brain, had the power to act spontaneously, to direct by their own sweet will the actions of the animal. These parts were then called centers, very much as we speak, without being able to give the word any literal meaning, of the center of a government or of a telephone central.

In our reflex arch we mean by center simply that neuron which is neither a sensory nor a motor neuron,—not having either of its ends in a sensory or motor point of the body.

We may, however, choose now and then to call the point $S\frac{1}{c}$ in an indirect, derivative sense a sensory point. But, to make this clear we must add to "sensory" a further, modifying adjective, for example, the adjective "central." That addition then has the sense of a negation, of a limitation.

Let us then call the point $S\frac{1}{c}$, on those occasions where we find it convenient and desirable, a "central sensory point." The addition means that it is not a sensory (sensitive) point of the body. This is no uncommon usage of language in science. In physics we call latent heat what is not heat, what has no temperature.

A central sensory point is a point in a nerve center from which one can trace a shorter path to a (real) sensory point than to any motor point of the body. In the same manner $M\frac{1}{c}$ will be called and regarded as a central motor point. From it one can trace a shorter path to a motor point (muscle) than to any sensory point of the body. That is all that is meant. Nothing else.

Speaking of sensory and motor nerve centers has been common practice in neurology from its early history. We have here merely defined these terms for our use more exactly than is customary.

Having called $S_c^1M_c^1$ a nerve center, we may add that it is a "low" or "lower" nerve center, for we shall later have to learn that there are also "high" or "higher" centers. The "lowest" center is that one which makes the shortest connection, the shortest among all those paths which may exist, leading from the definite sensory point to the definite motor point under consideration. In other words, each particular reflex function depends on the existence of a particular low nerve center serving the two "corresponding" peripheral points, sensory and motor. Peripheral, of course, is nothing but a common term including both sensory and motor. The literal meaning of "peripheral" is here entirely lost.

A student feels puzzled when he is asked the question if he could deprive an animal or a person of one of his reflexes by cutting it out with a knife. The question is really clear and concrete; and the answer is simply "Yes." Having a reflex means no more than having a definitely located "chain" of neurons. It may be difficult to determine its exact location. And it may be difficult to cut it out without cutting out other things too. But these are difficulties which exist in every surgical operation—in varying degrees.

CHAPTER III

The Other-One's Reactions are either Concerted or Local

The purpose of a reflex is to insure that the action take place in a certain locality when the stimulation occurs in a different locality. A reflex reaction so far as hitherto considered is a local reaction,—local in the sense of not being a general reaction or a reaction in many localities of the animal's body. But local action is not always the action which benefits the animal under the circumstances of the case. Let us look for examples from the Other-One's daily life.

The Other-One climbs a tree. He does that by applying two hands and two feet to the tree and its branches. Climbing without all four extremities is almost impossible. The four limbs must co-operate. That does not mean that the muscles of all the limbs must contract at exactly the same moment. But they must contract at about the same time. A contraction of one followed by a contraction of another one a minute later could not be called climbing.

As we have pointed out in another connection in a previous chapter, in order to understand, to make plain, to "explain" the facts, we must simplify them as much as possible,—in our imagination if we cannot do it actually. Is it possible, in this manner, to place all actions which are not "local" into one class and call them by one name? The title of this chapter seems to assert that this is possible. And it suggests as name the term "concerted."

Even in so simple an action as hitting a table with a fist a large number of muscles are involved. The very fist is the result of the contraction of certain muscles bending the fingers. The downward motion of the fist is the result of the contraction of certain muscles producing various motor effects, chief among them the stretching of the arm in the elbow joint. If these muscles remained contracted, the fist, after having hit, would press the table. Other muscles must immediately bend the arm at the elbow joint if it is to be a mere hitting without continued pressing upon. They must begin to contract even before the stretching muscles begin to relax.

Any such actions which occur (must occur in the nature of the case) either at the same moment or at almost the same time or in such quick succession that one is justified in saying they occur at about the same time, might well be called concerted. There is no need of limiting the meaning of the term concertedness. It may very well include actions, occurring at about the same time, which have various additional temporal or even other relations. This abstract statement will be illustrated by concrete examples of such mutual relations.

When one hears the word "concert," he thinks of music. That is not the original meaning of the word. It means really nothing but agreement in action. In European politics during the nineteenth century one used to speak of the concert of the Powers. But with no other kind of agreement in action are we so familiar as with that of a company of musicians playing before us. Their concertedness of action can teach us an important distinction relative to causes and effects, which we have to make also in speaking of concerted actions in any animal or in the Other-One.

The questions "Why do musicians play?" and "Why do the musicians play in concert?" refer to very different psychological causes. They play because (if we give a simple and striking answer) their stomachs are empty. The stimulus is lack of food. They want to make a living. The stimulation which causes the concertedness of their action is an entirely different one. This stimulus comes from their leader, their conductor, the director of the orchestra, or whatever you call him. They would not play if you offered to give them the sight of their conductor as a substitute for paying them money. And they would not (could not) play in concert (according to the highest standards) if you offered to put a ten dollar bill into each one's pocket as a substitute for giving them their leader. The stimulus coming from the conductor of the orchestra is a sign or sound made by him. If a musician does not make his tone at the right time or with the proportionate pitch or strength, the conductor of the orchestra acts as a stimulus which makes the laggard speed up or the bungler correct himself. The conductor of the orchestra, let us remember, does not function as the cause which makes the musician play, but as the cause which makes him adjust his playing.

In all concerted action we must carefully distinguish these two classes of stimuli: the class of stimuli causing each of the local actions; and the class of stimuli causing the concertedness of the several local actions,—whatever this concertedness may consist in.

Now let us think of some further examples of concerted action of his limbs in the life of the Other-One. Having climbed high up on a tree he wishes to pass from one of its large branches to one of the very near large branches of a neighboring tree. He passes along hanging. In this activity his two arms co-operate. Deprive him of the use of one

of his arms, and he cannot pass along the branches supported by one hand only. This is another example of concerted action. But it interests us not only as an example of concerted action. It interests us still more by being a concerted action which is a part of the concerted action of climbing.

Being a part of a complex, it is in a sense a local action. It is confined to the arms, whereas climbing is an action of both, the upper and the lower, pairs of extremities. An action, therefore, is concerted or local only in a relative sense. The same action is local in comparison with another of which it is a component; and concerted in comparison, of course, with another which is one of its components.

Walking is concerted action because it consists of action of the two legs in agreement. Walking is local action because it is action in the locality of the lower extremities only, not a concert of the lower and upper extremities as is climbing.

Standing on one foot is local action; and at the same time concerted, in so far as it involves co-operative action of many muscles. Picking an apple from a tree with one hand is likewise, in a relative sense, to be regarded either as local (one hand) or concerted (hand, arm, shoulder, standing feet, etc.). Treading the pedal of a machine with the right foot and feeding in with the right hand material for the machine to work on, is clearly concerted action; and yet it is purely local, right-sided, in so far as the left side of the body is inactive. The workman might have lost his left arm and his left leg.

When a student is asked what bodily actions his teacher, perhaps lecturing during a whole hour, performed during that hour, he replies: "He talked. He used his speech organs." And that would be a very exact statement, in

some sense; for example, before a jury in a court room. And yet, in another sense, it is very inexact. A local action confined to the speech organs is quite impossible under normal conditions. The lecturer not only talks, but also stands,—or sits, in accordance with his temperament. Standing is an action. If you do not believe it, if you think it means doing nothing, enjoying a rest, ask a recruit in the army. And sitting equally is an action. Is a hen enjoying a rest while sitting on eggs? Certainly not. And the lecturer, while more restful in the sitting than in the standing position, is less restful than he would be in the lying position. If all muscles relaxed, no sitting would be possible. Besides, the lecturer must keep his head steady. If it fell upon one of his shoulders or his chest, lecturing would be impossible

We see from this last example that a "local" action signifies only that the "main" muscular activity is confined to a certain locality in the body. It does not signify that there are no muscular activities outside of that locality. The latter, however, are of minor importance or seem to be so. A purely local activity in a biological sense is virtually impossible. But in a social sense, from the point of view of those among whom the Other-One daily lives, an action may be called purely local. It means simply that the only activity which, at a given time, was strong enough to be significant, conspicuous, worth mentioning, was the action at a certain locality of the body.

No newspaper reporter, for example, would mention that a politician addressing a certain audience, in addition to talking, kept his neck muscles under tension, washed his eyes by winking the normal number of times per minute, now and then swallowed saliva, and frequently shifted the weight of his body from one to the other foot. From a

social point of view the politician merely talked. He did not, for example, talk and dance. This, however, the reporter could rightfully have said of some chorus girl of the operetta stage, and he would then have reported a case of concerted action, where two actions, talking (with the speech organs) and dancing (with the feet) would have been equally pronounced and occurring in necessary agreement.

The pronunciations and the writing actions in the use of a language are both good examples of concerted action. Pronouncing "ferret" is a concert of muscular activities. Pronouncing "fret" is another one. The comparison of the two cases illustrates the importance of the relative force of each constituent action. In other cases of pronunciation the succession of the elements is of main importance.

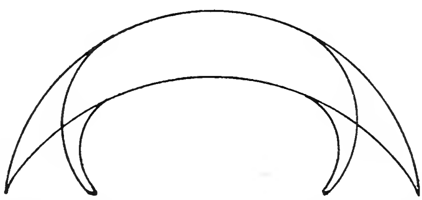
In writing it often happens that the succession of the elements is incorrect. A certain one of two muscle sets, both of which are ready for action, precedes the other one instead of being preceded by the other one. The author once knew a student who usually "lasped" into writing Odgen the name of his teacher which really was Ogden. The cause of it is obvious. In the English language the writing actions of d and g in this succession are a much more common form of concert than g succeeded by d. Think of badge, edge, ridge, lodge, cudgel.

These examples will suffice to keep us aware of the fact that it is never useful to think of concertedness in any but a relative sense. A concerted action may, according as it is compared, be local. In that case we shall regard it theoretically, that is, in artificial and intentional simplification, as a mere reflex action and represent it by a single reflex arch. In so far as we consider its real complexity, it need not consist of strictly simultaneous (but only of about

simultaneous) muscular contractions. The agreement of the several components may be of one kind or of another, of many kinds still to be illustrated by further examples. All that the term concertedness implies is a definite manner of co-operation of a definite number of localities of an animal's body leading to a definite real or apparent end. And the co-operation must take place within a period of time so small that one can speak of it as "the present" time. For example, "at the present time Robinson Crusoe is climbing a tree." Or, "at the present time he is walking."

The simpler the manner of co-operation of different localities, the easier it is to make it clear and understandable as the result of definite causes, of definite biological functions. In low animals the manner of co-operation of several local contractions is likely to be simpler than in high animals.

It is therefore advisable to study and understand clearly a case of concerted action in a very low animal. In the jelly-fishes the ordinary locomotion is a good example of concerted action. Let us study it in detail.



TWO CROSS-SECTIONS OF A JELLY-FISH.

A jelly-fish has a bell-shaped body. The figure shows it in cross-section. The so-called vegetative organs and the feet or tentacles have been omitted because they do not interest us in this connection. On contraction of the bell, in the manner indicated by the dotted line, the water—the medium in which the jelly-fish lives—is pressed out of the

concave side, and the animal, naturally, moves in the direction of the convex side. As a matter of fact, the movement of a jelly-fish in the water is rarely seen to be as simple as our statement suggests. The usual position of the animal is with the cavity downwards, tho not necessarily with the axis exactly in the vertical position. And its usual locomotion is oblique rather than in the direction of the axis. But, as we have previously justified it in general, so we here as elsewhere simplify the actual case and regard it as a motion along the axis in the direction of the convex side.

It is plain enough that a straight-way locomotion could then result only under certain conditions. For example, it would be impossible if the tissues on one-half of the rim of the bell contracted while those on the other half relaxed, expanded, or even only lagged behind a little in contracting. This lagging behind, however, could easily be brought about by the uncontrolled play of certain conditions,—which we now have to study.

To understand these conditions, let us first imagine the analogous case of eight leaky places on a water pipe. Suppose the frequency of the dropping at each place to be about the same, say, one drop a second. But even then we could not expect all the eight drops to fall simultaneously: as we say in physics, we could not expect that there be no phase difference among the eight drops. The eight drops would probably fall from the eight leaks in a quite irregular succession. Let us make the application of this analogy.

The rhythmical contraction all around the rim of the bell would be caused by the chemical constitution of the jelly-fish at the time in question, when perhaps no food has been taken for some time and locomotion thus has become necessary. Now, lack of food is a very slowly developing,

slowly acting stimulus. The excitation resulting from it has a chance to distribute itself continuously all over the body,—to distribute itself more quickly than it develops. It is therefore quite impossible that it differ appreciably in various parts of the body at the same time. The excitation being the same in all the divisions of the rim of the bell, no division would on account of stimulus and excitation have a frequency of periodic contraction differing from that of any other division. Of course it is here presupposed that, the greater the excitation, the greater the frequency of the resulting contraction.

In spite of the uniformity of the excitation (the chemical condition) thruout the body, however, there might be a slight difference of the frequency of the bending inwards of the divisions of the rim, if the tissues happen to be unequally flexible. In consequence of a wound there might remain a scar, and the tissues of this region might therefore, or simply by accidents of growth (what animal could be absolutely perfect in symmetry!) be a little more or a little less tough than elsewhere. A difference of frequency would result.

What would be the result of a difference of frequency for the locomotion of the animal? If of two paddle wheels on the two sides of a steamer one would go faster, strike the water more frequently, what would be the result? The steamer would continuously turn to one side, gradually describe a circle. That would help little to remedy the evil of lack of food,—in the analogous case of a jelly-fish.

Now suppose the frequency of contraction, fortuitously, to be the same everywhere. That would by no means insure that the contractions occur in all the divisions of the rim of the bell simultaneously. There would be as little probability for that as for the falling, simultaneously, of

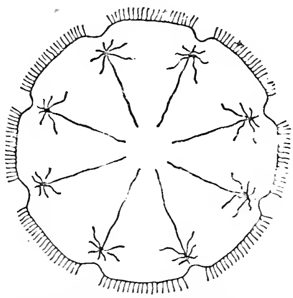
those eight drops at eight leaky places of a pipe. And what would be the result for the locomotion of the animal? The same as if several boatsmen rowing a boat in a race would not drop their oars in the water simultaneously, but in irregular succession. The boat would not advance in a straight line, but wabble, so to speak, irregularly and jerkily from either side to the other. That would be a considerable waste of effort.

Could the simultaneity be insured? In the boat race it is insured by the captain of the team, who, if necessary, counts aloud. His words are not the stimulus which makes the oarsmen work. (We remember the conductor of the orchestra!) His words are the stimulus which makes them correct the imperfections of the concert of their actions. The boat no longer proceeds in an irregular serpentine, but in a straight line. It has a chance to win the race.

In the jelly-fish, as soon as one of the divisions of the rim of the bell "spontaneously" (that is, in response to the stimulus "lack of food") begins to contract, this contraction itself assumes the role of a stimulus. From it results a new excitation,—in the very tissues contracting, an addition to the excitation previously existing in them, which has caused their contraction. But what becomes of this new excitation?

All tissues are, as we know already, to some degree sensitive, contractile and conductive. The new excitation is therefore conducted to all the other divisions of the bell, even tho there be no differentiated conductive tissue. Those other divisions are almost ready to contract, in response to the stimulus "lack of food." They would contract in any case, one soon, another one just a moment later, and so forth. The additional excitation reaching them "speeds them up," causes them to contract now, all of them virtually

at the same moment. One must remember in this connection that the velocity of propagation ("velocity," not rate, not quantity of flow) of any small unit of excitation is quite considerable; probably not much less than 100 feet per second. And from one side of a jelly-fish to the opposite is a distance of only a few inches. So all the divis-



NERVOUS SYSTEM OF A JELLY-FISH (ACALEPHA).

ions would contract virtually at the same moment. In physical terminology,—that is, in the mathematical terminology of the physicist,—one would say that the phase difference of the periodic contractions of the various divisions was zero. What now about any possible differences of their periods,—or (since this means really exactly the same) of their frequencies?

We have made it clear previously that a difference of frequency is much less likely than a difference in phase. The stimulus "lack of food" is a slowly developing stimulus, the excitation is therefore evenly distributed; and considerable differences in the toughness of the tissues are probably rare. If any difference in frequency is to be expected, we would expect only a slight one. And frequencies differing slightly would readily be equalized by the same factor which does away with the phase differences. If those divisions of the rim of the bell which lag behind, are forced to con-

tract at the moment when the first contracts, and thus at the beginning of the next period again all contract at the same moment, and again and again, there can obviously be no frequency difference.

In the locomotion of a jelly-fish the concertedness of the actions of the various divisions of the animal consists in the fulfilment of two conditions: in equality of the frequency of the various local contractions and in the phase difference of their periods being zero. And this concertedness—we understand now— is brought about simply by the fact that a contraction of tissue, altho resulting, of course, from a stimulus, can itself be a stimulus. This latter stimulus is analogous to the class of stimuli coming from the leader, in the example of the orchestra. Naturally, there is no special leader in the body of a jelly-fish. Any part may accidentally assume this role. The stimulus "lack of food" is analogous to the stimulus "lack of food" in the other case.

We shall later see that in the highest animals, too, contraction of contractile tissue may be itself a stimulus. Indeed, the muscles, for that reason, must be regarded, not only as motor organs responding to sense organs, but themselves as sense organs to which other muscles may respond. This interesting fact, altho it suggests itself, cannot be discussed further at this moment, since that would interrupt our present line of thought. But this may still be said in this connection, that one must not think it strange that the muscles should have two different functions. In fact they have still other functions. They are also the "stoves" which heat the body. And they are organs of secretion which, as such, like glands are of much importance. Biologically there is nothing strange in an organ having a multiplicity of even diverse functions.

Equality of frequency and phase is one example. Serial occurrence is another example of concertedness. We find serial occurrence of actions in the highest as well as in the lower animals. All writing and speaking can furnish examples. Or an experience of the following kind.

Think of an insect alighting on your nose. Many are the responses which may occur. But which of them in all probability will be the first? Most probably you twitch or wriggle your nose; the insect is disturbed and leaves. No further action then follows,—there being no further stimulus. But the insect may have such a good hold on your nose that such slight movements will not cause it to leave. A second reaction occurs. You shake your head. But if this does not remove the insect, and if the stimulus, therefore, persists, you make a hand movement. With which hand? If you are what most people are, right-sided (this is a better designation than right-handed), you move the right hand. This will surely brush the insect off, if your hand can reach the nose. But imagine you are a captive among Indians and tied to a tree. The third reaction, that of the muscles controlling your right hand, therefore remains as ineffective as those preceding. Your fourth reaction will then be that of your left hand. It is ineffective like the third. Your fifth reaction is that of the right foot. Why should you not try to take a reed or a similar thing between your toes in order to brush the animal off? People who have no hands may be seen to take even a writing pen or knitting needles between their toes! If the right foot does not succeed, the sixth reaction may be that of your left foot. And after that a general twitching of all the muscles of the body may follow, general convulsions. You would not, with a mere sigh, permit the insect to destroy your nose in the manner in which in the classical paintings Prometheus reacts to the vulture gnawing his liver.

The reactions in a case like our example are not likely to occur in an irregular series, but in a definite one. And in a series, not simultaneously and immediately.

Similar to serial reactions are circular reactions. The simplest circular reaction, consisting of two members only, is alternation. With alternate or reciprocal actions we are very familiar in engines. The piston of a steam engine, going one way, operates a lever which initiates its going the other way; this makes it go again the former way, and so forth. The heart of animals consists essentially of two chambers thru which, because of self-closing valves, the blood can pass only in one direction. The contraction of one chamber acts on the other chamber causing it to start contracting. The contraction of the other acts on the one, and so forth.

At a first glance all that seems necessary biologically in order to bring this about is the fact already mentioned, that a contraction becomes itself a stimulus, that is, the cause of an excitation. This excitation is conducted to the other muscle. The other muscle then contracts and, as a stimulus, causes in itself a new excitation, which is conducted to the former muscle, and so forth. If we, accepting the responsibilities of the Creator, desire to improve the conduction, we do that by introducing differentiated conductive tissue. We take two reflex paths, put the sensory end of one of these "chains" of neurons in one muscle and its motor end in the other muscle. In the latter muscle we place also the sensory end of the other neuron chain; and the motor end of this we locate in the former muscle. Two reflexes joined in this manner seem to be all that is necessary for this form of concert. If there are three members in the circle of action instead of two, three reflexes are joined end to end. And so forth with higher numbers.

In a true series,—not occurring in a "circle" like pump actions, but running along a "line," from one end of the series to the other without repetition of the series,—nothing more seems to be required, either, than a number of reflex paths joined and one initial stimulus from outside the muscle group. Draw some reflex arches side by side as in a previous figure, but join the sensory point of the arch on the right to the motor point of the arch on the left. Continue adding in this manner as many reflex arches as you wish. This looks like a simple solution of the architectural problem confronting the Creator in any case of serial or of circular action.—But it is not.

The solution just suggested may solve the problem in many of the simpler cases. But it is far from being a solution generally possible in biology. Two conflicting conditions seem to make life impossible. The problem would be hopeless if a complete denial of the demand of either the one or the other were insisted on.

But what are these two conflicting conditions?

One is the need, in the life of animals, of concerted action of various kinds. The other condition is the need of local responsiveness in the sense of one action being overwhelmingly strong in comparison with the responses occurring at the time in other localities of the body.

It would be terrible if a jelly-fish, for example, could move only in a straight line without ever changing its direction,—if a contraction of one division of the rim of the bell would invariably force all the other divisions to contract at the same moment. It would be terrible if the ability of a boy to climb a pole straddling forever precluded the possibility of moving his hands alone, that is, without alternately moving now hands, now feet, again hands, again feet, and so on,—if he were thus condemned to be all his life a kind

of jumping jack, if he could not eat without exercising at the same time "half bend of the knees." It would be terrible if chewing, swallowing, and pushing things down the esophagus, which often occur in this order in a series, could never occur otherwise,—if chewing could never be followed by spitting, and swallowing never by vomiting.

And yet these terrible consequences seem to be inevitable if concerted action is always and only the result of perfecting the conductivity of the tissues concerned, or, in the higher animals, of joining reflexes together. How can the reflexes, by functioning separately, give the animal local responsiveness, if the very cause of their existence, the separateness and localness of the response, has been denied by joining them in groups or series?

On the other hand,—this is the dilemma—how can concertedness be the result of anything else but of the conductivity from acting member to acting member of the interposed tissues, or of the junction of several reflexes? The reflexes must be joined. The problem is obviously, not merely a problem of joining or not joining, but rather of joining in the proper or in an improper manner. It is a problem, seemingly, of architectural design within the conductive tissue, within the nervous system. In order to force yourself to understand the problem better, imagine yourself to have received from the Creator an appointment of serving as his assistant, to have received the task of constructing for the benefit of a given animal a nervous system which will fulfill its needs. It is the same as in understanding any engine, a sewing machine, a clock. Put its pieces together so that it works, and you have made its function perfectly clear to you.

If you cannot actually, materially, construct the machine, you can construct it by making a drawing, putting the

elements together on paper. Design a nervous system by joining together reflex arches, as if you were the Creator's architectural deputy. That will make you understand the problem and at least some of the possibilities of its solution.

This does not mean, however, that you have any right, taking the interest of science at heart, to indulge in any fanciful designs of a nervous system unrelated either to the facts of the animal's behavior or to the neurological knowledge of the time. You must, indeed, limit yourself strictly to the results of anatomy, histology, physiology, organic chemistry, etc. But where the knowledge of the facts by contemporaneous science is incomplete, you not only can but must fill the gaps by hypotheses.

A scientific hypothesis has a double value. First, it satisfies an intellectual person's practical need of understanding what he experiences. The hypothesis is not "the known," but it is "an analogy of the known." Human as we are, if we do not satisfy our desire to understand things at least by constructing an hypothesis, we fall easily into the habit of completing deficiencies of knowledge by imagining mysteries as causes. And secondly, a good hypothesis has the immense value of spurring us on and showing us the way in research, of pointing to a fruitful direction in which to look for facts whose knowledge may in the future be substituted for the analogies of which an hypothesis is constructed.

What, then, will be the hypotheses of nervous architecture and nervous function by means of which you fulfill the imaginary task given you by the Creator?

CHAPTER IV

Concerted Action presents a Problem to the Architect of the Nervous System.

In modern discussions of the function of the nervous system a phrase is often found which we have thus far avoided. One hears much about "the integrative action of the nervous system." This phrase means exactly the same as what is expressed by saying: "Concerted action depends on the architectural and functional properties of the nervous system." It is likely to be misunderstood by an inexperienced student as meaning that the nervous system's only function is that of integrating, "making a whole," insuring the concertedness of the animal's actions. But the previous chapters have shown us the very opposite of integration. The separateness, the localness of a response to a stimulus is also a purpose of the existence of the nervous system. And the latter purpose is no less exacting in its demands than that of unifying the animal.

What does "concerted action" ask of the architect of its house, so to speak? What is the most general demand made on the nervous system by concerted action? Is this not readily agreed on by all the parties to the contract, that some nervous current, no matter whence it comes, must be able to go to all those points where the contractile tissues are located which are to act in concert? Must not the leader of the orchestra be able to reach all, be visible and audible to all the musicians?

No one believes that this is sufficient, and that, this demand granted, all problems have disappeared. But, thinking of the problem of concertedness in the simplest possible way, this is certainly the most fundamental necessity. Some current must go to all those points.

In the case of the jelly-fish—as to coming— we saw that this current came from one of the contracting divisions of the rim, caused by the contraction itself; and—as to going—that it went everywhere because of the conductivity of all the tissues.

The question remains if this current would not be too weak if it had to pass wholly thru undifferentiated tissue. Now, it need be only weak because, as we remember, it has to hasten only, not to cause, the contraction of the several divisions. Nevertheless, it might be too weak. Then the Creator would have to come to the animal's aid as the architect and builder, would have to furnish it with differentiated conductive tissue. Turning back to our figure of the jelly-fish as seen from above, we notice there radiating nerve fibers serving this purpose.

If the Creator has appointed you to place these fibers in the animal so that they serve this purpose best, you will probably connect them all in one point. You will make them all radiate from one point. Then good conductivity from any division of the rim to any other division is insured.

Nevertheless the animal, if it can speak to you, its "benefactor," and if it is wise, will protest against this gift. Frequently external stimuli act upon the body and require, not a straightforward locomotion, but a change of direction as response. For example, the jelly-fish, while swimming, strikes a rock with one side of the bell. The jelly-fish then must change its direction. That division which touched

the rock must contract more strongly than any other, especially than the diametrically opposite division, in order to bring about the change of direction. Without conduction, the predominance of the action of the one division touched would be certain. But with perfect conduction to all other divisions it would be equally certain that no such predominance of a local reaction, no local responsiveness to an external stimulus, would be possible.

We only repeat here. We have already referred to this fact, the impossibility of such a conductive system, in the second chapter, while discussing the life of our imaginary snail.

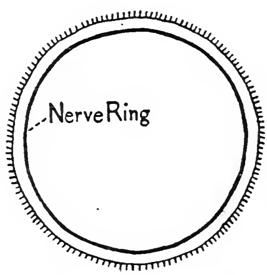
Here is, then, the necessity for a compromise. And this compromise is effected in the jelly-fish by having the eight radial fibers not join in the center, but stop short before reaching each other. Thus undifferentiated tissues, tissues of high resistance, are interposed to weaken the excitation coming from one of the divisions to such an extent that only one division can react strongly to the external stimulus. All others react only weakly.

It is interesting to note that compromising, which is the very foundation of all social life of animals, of all social institutions of mankind, is found to be an essential function in the individual life of any one of the very lowest animals which possess a nervous system. The unity of all organized nature, which is the fundamental concept of modern biology, is exemplified by this role played in any life, low or high, by compromises. Two conflicting conditions seem to make life impossible. But the problem would be hopeless only if a complete denial of the demands of either the one or the other were insisted on. On the one hand, concerted action calls for the most perfect conduction from any division of the rim of the bell to all the others. On the other hand,

local responsiveness calls for the interposition of high resistances between the diametrically opposite divisions of the rim. The compromise must then consist in this, that all the divisions are connected by conductors, but in such a way that conduction from one point of the rim to opposite points is by the properties of the conducting medium itself more resisted than conduction to neighboring points.

Nature has, as we saw, solved the problem by stopping the differentiated radiating conductors as far short of the center as the condition of local responsiveness requires, leaving in the center enough undifferentiated tissue interposed to meet this requirement. Another way of fulfilling the condition of varying resistance is by resorting to the length of the differentiated conductors without interposing any undifferentiated tissue. There can be no doubt that the length of a nervous conductor determines its resistance as the length of telegraph and telephone wires determines their resistances. The longer the conducting string, the greater its resistance.

Nature has solved the problem in this way in another kind of jelly-fish, called hydromedusa. Here all the points



NERVOUS SYSTEM OF A JELLY-FISH (HYDROMEDUSA).

of the rim are connected by differentiated conductors forming a ring, as shown in our figure illustrating the nervous system of this species. If any division of the rim contracts,

the excitation is by this ring conducted to all other divisions. But the excitation reaching opposite parts of the rim is much weaker than that which reaches neighboring ones, in accordance with the varying length of the conductor. This difference in the intensity of the conducted excitation does no harm in the case of ordinary, straightforward locomotion. The rhythmical contraction is in this activity the result of the chemical constitution of the body which, perhaps, has been the result of lacking food for some time. This chemical state differs but slightly in the various parts of the body. The different parts of the rim, therefore, would contract and expand in almost the same periodicity anyway. A very slight excitation conducted from elsewhere is then sufficient to hurry up any part which without this excitation would lag behind. Thus there is concerted action.

But when a stimulus acts from without on any point of the rim, only those parts are caused to respond strongly which are in that neighborhood. The other parts of the rim, receiving the effect of the stimulus as a weaker and weaker excitation the longer the piece of the rim over which the excitation has to travel, are considerably affected only if yet rather near the point of stimulation. The divisions opposite this point remain practically unaffected by the stimulus. There is local responsiveness.

The problem of combining undisturbed local responsiveness with universal connection of all the parts of an animal's body by conductors of low resistance can therefore be solved architecturally in more than one way. Our figures of the two species of jelly-fishes represent two solutions of the problem, both actually found in nature. But the second solution seems the more perfect one, because the universal communication thru conductors is in this case more perfect, while local responsiveness is as satisfactorily retained as in

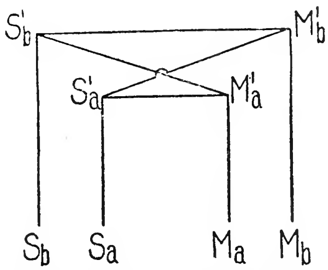
the other case. This more perfect solution of the problem resorts to the differences of the resistances of the conducting paths as dependent on their varying length. We shall have to keep this in mind.

The example of the jelly-fish has taught us that there must be a gradation of resistances. Imagine a sensory point called A and a motor point called B. If it is desirable for an animal's well-being that an excitation occurring at A be followed most readily by a contraction at the point B, the points A and B must be connected by a conductor of small resistance. Let us call those sensory and motor points which are thus connected corresponding points whenever we need a brief term by which we may refer to them.

If, as in the case of a jelly-fish or a snail, these corresponding points are virtually identical, only different names for the same place perhaps, the conduction is a self-evident fact even without any special conductors. If, as in the case of the moth, A is an eye and B the muscle of a wing, at a distance from each other, the conduction between the corresponding points must be mediated by a nervous string, or a chain of nervous strings, of the shortest length possible under the anatomical conditions. But all—or at least some—of the other, non-corresponding, contractile points of the body must also be in some way connected with the sensitive region A. Otherwise no concerted action might be possible. The moth, for example, would hardly be able to alight on a twig or leaf which happens to impress itself on the animal's eye and towards which the moth must act, not only with its wings, but also with its legs, in order to alight. These further connections with the point A, however, in order to leave the connection A-B in its proper functional condition, must have a higher resistance,—as we have seen, must be longer than A-B.

The shortest possible connections between corresponding points are exactly what we have called in a previous chapter reflex arches. We must now find a way of representing graphically those nervous conductors which lead from each sensory point to those motor points which are not corresponding.

These conductors which are not reflex paths must be, as we have found, longer than the conductors directly connecting corresponding points. It is clear, then, that no good purpose could be served by representing the connections between non-corresponding points as they are represented in our figure showing two nested reflex arches. The figure is intended to demonstrate merely how neurological functions ougth not to be—but how they nevertheless sometimes are—described.



A WRONG DESIGN OF CONNECTIONS.

Let us agree that any straight line, no matter what its length, shall represent one neuron of standard length and of a unit of resistance. Such lines as $S^1_aM^1_b$, which has a crook between its straight ends, are also regarded simply as straight lines, because the crook signifies nothing but insulation from the line crossed on the paper. All this is customary in such drawings. We then measure the resistance of a path in the drawing by counting the number of lines of which the path is composed. This number gives

the resistance of the path in units. The conductivity is inversely proportional to the resistance and can be measured by the reciprocal value of the resistance. For example, if a certain resistance is 4, the conductivity is $\frac{1}{4}$; and if the resistance is $\frac{3}{4}$, the conductivity is $\frac{4}{3}$.

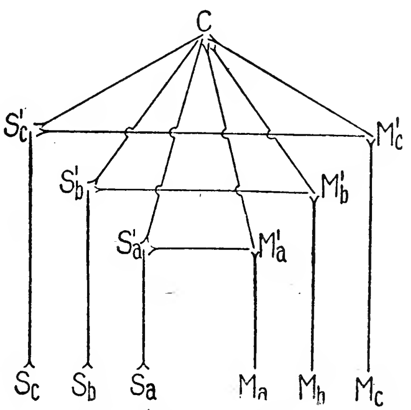
Now imagine the connections between non-corresponding points made by nature as in our drawing. Count the units of resistance. The conductor $S_b S^1_b M^1_a M_a$ connecting the non-corresponding points S_b and M_a has not a greater resistance than the conductor $S_b S^1_b M^1_b M_b$, since both are made up of three standard lengths, altho our requirement is that it shall have a greater resistance, a lesser conductivity. We must look for a different design in order to represent the actual conditions of conductive connection properly in a graph.

Neurology, that is, the anatomy and physiology of the nervous system as it actually exists and functions in animals and in man, teaches us an important fact which we ought to represent in any diagram of nervous connections. It has been found that the same two points (one sensory and one motor) are almost always connected in several ways, by shorter and also by longer conductors. For example, if pain is caused in a dog's foot and the foot is withdrawn, the nervous excitation may travel from the foot to the spinal cord and thence to the muscles moving the foot. Or, it may travel from the spinal cord farther on to the dog's brain, thence back to the spinal cord and now only to the muscles.

In an early stage of neurology a merely two-fold connection, including or not including the "brain" (a somewhat indefinite something), was supposed to exist. One then spoke of two neural "levels" to which the lower and the higher "nerve centers" (another rather undefined something) belonged. The number of these so-called levels of

connection was later increased to three, and three classes of lower and higher centers were spoken of. From three the number grew to four. And so forth. Today there can be no doubt that the number of different levels of connection is very great. It may be among the hundreds or thousands. The total number of neurons available for the architecture of the nervous system is so great (five thousand millions or more) that in a human being certainly even a thousand levels of lower and higher centers are far from impossible. It seems best to keep out of this field of speculation. However, there is no reason for thinking of the number of different levels of connection as being very small.

He who thinks only of a two-fold connection of greater and lesser length between corresponding points, and re-

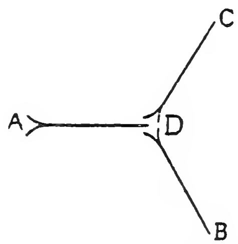


A WRONG DESIGN OF A NERVE CENTER.

members our requirement that the connections of non-corresponding points shall be longer than the (direct) connections of corresponding points, will readily suggest to us as a suitable design for the architecture of the nervous system our figure showing three nested reflex arches and additional neurons radiating from the center C.

In this figure we can travel from, say S_a, to the corresponding point M_a over a longer route by C (four standard lengths), or over a second and shorter route (three standard lengths) avoiding C. And we can travel from S_a to a non-corresponding point, say M_b, only over a longer route $S_a S_a^1 C M_b^1 M_b$ of four standard lengths. The same rule holds good for other combinations of sensory and motor points.

Before continuing the discussion of the question whether this is a suitable architectural design for a nervous system, we may use this opportunity of making clear why we have drawn each conductor, each neuron, in the shape of an



CHECK VALVES AT A MEETING POINT OF NEURONS.

arrow-like rod. We can easily agree and remember that the point of any arrow shall mean that no excitation can enter here from any other neuron, whereas the split end shall mean that an excitation can enter here, but cannot pass out. In our figure with the lettering A-B-C-D three neurons meet in one point, D. An excitation here may pass from AD into either DB or DC, but no excitation can pass from either CD or BD into DA. It is as if a multiple check valve located at D allowed the flow of a fluid in one direction, but prevented the flow in the opposite direction. The facts known to neurology not only permit, but seem to force us to assume that the meeting point of two or more neurons functions like a check valve.

Experiments have proved, it is true, that an excitation may travel in a neuron in either direction. But normally no excitation originates within a neuron. And with respect to the propagation from neuron to neuron, neurological experiment and observation seem to agree with the view expressed in our drawings.

Everybody knows that our feet are connected with our eyes as well as with our ears; of course, also with other sense organs. If a strange and ferocious looking animal suddenly appears to any ordinary person's eye while he is sitting, he jumps up and starts running—on his feet. If he is sitting in the theater, and suddenly the fearful cry "fire" strikes his ear, he also jumps up and starts running—on his feet. That is, the muscles moving his feet are connected with his eye as well as with his ear.

But his eye and ear are connected with many other muscles too. Else, for example, he would not turn his head in response to a friend's call or eat what is placed before him on the dinner table.

Neurologists have discovered in the brain the so-called motor region of the feet. If this region of the brain is artificially stimulated, the muscles belonging to the feet contract and move the feet. Suppose the excitation caused in the brain by this artificial stimulus could proceed, not only in the direction of the motor organs most closely connected, but also in the direction of sense organs; then a good deal of it would go to the eye and the ear.

The eye and the ear, receiving the artificially produced excitation from the brain, would send it on to many muscles of the body. It should then have been observed that in response to the artificial stimulation mentioned not only the feet, but many parts of the body moved. If such were the case, the neurologists would never have discovered the motor region of the feet.

We are justified, then, in our assumption of a one-way propagation of an excitation from neuron to neuron, always "away from the nearest sensory points and toward motor points."

The anatomical connection between neurons is of such a wonderfully elaborate kind, that it seems quite probable that the meeting points have some peculiar functions. This is quite likely to be one of them,—to serve in the manner of check valves. The neurons do not run into each other like wires soldered together, but the end branches of one surround in a curious way the end of the other neuron. This has been called synapse. The word "synapse," of Greek origin, has exactly the same meaning as the Latin word "contact." The contact between neurons is of a peculiar kind, so much so that some have said it ought not to be called contact at all,—and have called it synapse. We shall speak of it again at a later time.

We must now return to the question whether the design of our figure showing three nested reflex arches is suitable for the architecture of the nervous system. It would be, if we could restrict ourselves to thinking of only a two-fold connection between corresponding points, to thinking of only two levels, two classes of (lower and higher) nerve centers. But such a restriction is impossible. A concrete case will easily show why.

We recall the kind of concerted action which, in the preceding chapter, we called "serial" action. Remember the example of the irritating insect sitting on your nose. Nature has enabled you to respond by a series of movements, beginning with easy ones, continuing with those which are increasingly cumbersome. If at any moment the stimulus is removed, the series of movements is discontinued. What will you do, if you have accepted the position of assistant

to the Creator and you have been given the task of designing a nervous system which will make possible such serial activity?

First you will ask yourself if the condition of a successive occurrence of these actions can possibly be reduced to a condition of a mere gradation in the conductivity of various nervous paths. You will recall that it is well known that many muscles of the animal body are so made that the contraction does not begin at the very moment when we have reason to believe the excitation begins to act on the muscle, but only after the excitation has had an opportunity to accumulate the effect on the chemical condition of the muscle up to a certain degree.

It is like balancing a plank on a fence post which is flat on top, placing an empty bucket on one-half of the plank not too far sideways to disturb the balance, and slowly pouring water in the bucket until the bucket spills the water. When will it spill the water? The first few drops pouring into the bucket will have no visible effect on the plank. But after a while the bucket will become heavy enough to disturb the balance. The plank will tip and all the water will be spilled at once. "All or none." The greater the rate at which we pour the water in the bucket, the sooner the bucket spills. If the stream running in is very weak, the bucket will spill its contents only after a very long time.

Interrupting our thought here a moment, we may mention that an excitation on entering a muscle is often given the name of "innervation." This word has it origin in the thought of a "nervous" excitation passing "into" a muscle. We can use the words "excitation" and "innervation" indiscriminately, for passing into a muscle (or gland) is the purpose of every excitation which has its origin in sensitive tissue. It is not customary, however, to use the word "in-

nervation" except when the excitation is discussed as entering into a muscle.

The innervation, then, can be said to accumulate in a muscle until its accumulation has reached that degree which the muscle requires before it contracts.

Then we can indeed reduce the condition of a successive occurrence of movements to a condition of a mere gradation in the conductivity of various nervous paths.

The sensory point on the nose must be connected by a nervous path of low resistance (that is, by a very short path) with the muscles of the nose, by a path of more resistance with the neck muscles shaking the head, by paths of further increasing resistances with the right arm, the left arm, the right foot, and so forth.

Where the resistance is greatest (the conductivity lowest), the flow of the excitation is smallest. Where the resistance is small, the nervous current is strong in proportion. In accordance with the strength of the current, the various muscles receive a sufficient amount of innervation after a varying length of "latency." This means that during a varying length of time the presence of the excitation, accumulating in the varying muscles, remains "concealed." It remains concealed until "the bucket spills."

The strongest current goes to the nose. The muscle of the nose "spills" first, so to speak. That is, the first reaction is a twitching of the nose. The neck muscles contract second. Those of the rigth arm, the left arm, and so on, contract in the succession corresponding to the increasingly great resistances of the nervous paths. If, however, the stimulating insect is at any moment brushed off, from that moment the current of excitation ceases, no further accumulation of innervation takes place in any muscle, and no further contraction and movement are observed.

The three nested reflex arches with their connections by additional neurons at C, obviously do not make possible any array of nervous paths in accordance with the condition that every path from the same sensory point to another and another motor point shall have a different resistance. In the design a single path—we have seen—has the resistance of three units; and all others (in the design only two others —but any number equal to the number of arches drawn, minus one) have the same, invarying, resistance of four units. If the stimulus acts on the sensory point S_a, the motor point M_a reacts first (under the assumption made). But the motor points M_b and M_c would not react successively to the prolonged stimulation, but simultaneously. We must therefore look for another architectural design, if we want to fulfill the task which we imagine ourselves to have accepted from the Creator.

A very simple consideration convinces us that it is a mistake to try to represent a nerve center by a point.

In the design of a reflex arch the horizontal line represents a nerve center. The lines falling down from it represent sensory and motor neurons. The "synapses" belonging to the horizontal line may be regarded as belonging to what we wish to call the nerve center. This nerve center is, of course, a "low" nerve center. Its two "synapses" may be temporarily considered as if they were a sensory and a motor point. In this sense we have in a previous chapter called them central sensory and motor points.

Nothing prevents us from placing over a pair of central sensory and motor points an arch exactly like a reflex arch placed over a pair of peripheral (true) sensory and motor points. Nothing prevents us from placing over this second arch (the second story of the architecture, so to speak) a third; over the third a fourth; over the fourth a fifth; and

so forth, as long as there is any necessity, functionally, for going to higher and higher levels of connection.

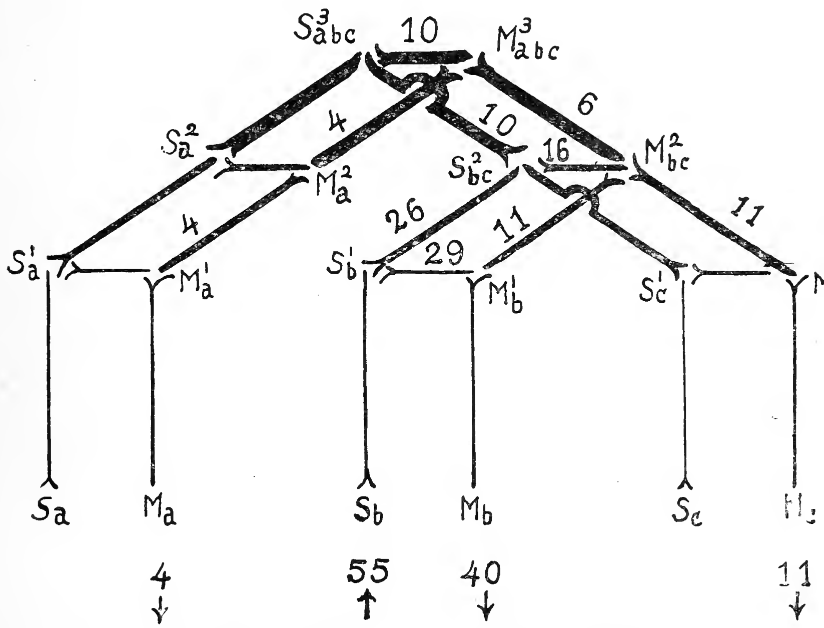
But if over a pair of central sensory and motor points a higher story is placed which consists only of neurons falling from a single central point, C, no further arch can be placed over this single central point. We have then reached the highest nerve center, beyond which no higher center is even thinkable.

Everything we know about the anatomy and histology of the nervous sytem and about the behavior of animals contradicts such a conception of the architectural plan of the nervous system. If we wish to play out a trump, we can say that such a conception of a nervous system with a fixed ordinal number (second, third, or higher, but fixed) attached to the highest possible nerve center is a flat denial of the theory of evolution. The evolution of the nervous system consists, in higher animals and Man, in the evolution of higher and higher centers, making more and more indirect connection, more and more varied combination, of the existing reflexes possible. There can be no limitation of this evolution.

The higher centers must be arches just as the lower centers are arches. And the connection between any juxtaposited arches must be made by a center which is higher than either center of these two arches. The main feature of a center, in a drawing, is a horizontal line and never a single point.

The principle of design for the connection of two (or more) arches by means of a superposed arch can be stated thus: In order to draw the superposed arch, always draw first its horizontal line in a convenient position, and mark the end points of this line S and M. Then drop from the S point as many "shunted" sensory neurons (legs, so to speak)

as you have S-points in the story just below, in order to reach these S-points. And from the M-point of the horizontal line drop an equal number of motor neurons (legs) to the M-points just below this level. The accompanying figure shows the method of design clearly by drawing the arches the blacker, the higher the centers.



A USEFUL DESIGN OF HIGHER CENTERS.

The principle does not demand that there be (as in this figure) two arches, one above the other, both over the points S^1_a and M^1_a, tho in series, so to speak, not shunted. One arch $S^1_a S^3_{abc} M^3_{abc} M^1_a$ might suffice, according to circumstances. It must be understood that in this special drawing no special demands have forced us to draw an arch with the roof line $S^2_a M^2_a$ This might have been left out. Nature can do the one or the other.

It is also perfectly arbitrary with respect to the general principle of the design that we have left out the second

pair of legs in the second story arch just mentioned. It is only our wish to illustrate serial activity which has made us omit the two otherwise possible neurons $S_b^1 S_a^2$ and $M_a^2 M_b^1$. If this serial activity was not, but some different activity was desired, and the latter demanded these neurons, their places could be filled.

Where from any central point two (or more) legs branch out in the direction of an equal number of lower centers, we can conceive of them as so many neurons or as so many long branches of the same one neuron. Histology reveals both these methods as actually serving such necessities.

The nervous system which we have designed, we have designed with the well understood intention, as we said, of playing the Creator's role in helping an animal to possess three qualities: first, that of being capable of responding locally; second, that of responding by several movements strictly simultaneously, the nervous system preventing any lagging behind or failure of a movement to occur,—preventing it by regulating the movements thru some common excitation reaching at the proper moment all the motor points concerned; third, that of responding to a given stimulus by a series of different movements in regular order. Our three-fold problem seems to have been solved. That is, we have seen, at least, the possibility of shifting the problem from the field of mystery into the clear field of mechanics.

First: if S_b is stimulated, more of the current goes to M_b than to any other motor point. The response is "local."

Second: if S_b is stimulated, some of the resulting current can, virtually at once, reach all the motor points of the system, M_a, M_b, and M_c, to speed them up.

Third: if S_b is stimulated, most of the current goes to M_b, less to M_c, and still less to M_a. In the last case there

is only a single path leading thru seven neurons. In the preceding case the shortest path consists of five neurons, and the figure shows an additional, shunted, path over the highest center, making the total resistance less than five units. And in the first mentioned case the figure shows, in addition to the reflex path of three neurons, two shunted paths over higher centers, making the total resistance much less than three units. Serial activity is possible.

Even a mechanical phenomenon can be made still clearer than it naturally is on account of not forcing our imagination outside of the simple experiences of matter and motion. It can be made still clearer by applying computation.

The arithmetical values of a computation in any situation in business as well as in school studies give additional satisfaction over the satisfaction derived from a mere knowledge of "more or less." Or do we not prefer, for example, after having heard a tradesman assert that he sells shoes cheaper than his competitor, to hear him say that they are 50 cents cheaper?

Let us, then, compute how any conveniently chosen number of units of excitation distribute themselves thru the various channels of our last figure. The whole conception of a distribution of an excitation, let us mention by the way, is a rather recent discovery.

Twenty-five years ago hardly anybody thought of a nervous process in any other way than of something rolling along like a golf ball over a rough field, striking here and changing direction, striking there and changing direction, without breaking up, always remaining the same whole ball. This conception has now become recognized as utterly impossible. The nervous process is a current, a stream, lasting as long as the stimulus lasts. The nervous current distributes itself like electricity, or water, or gas in a city's net-

work of distributing wires or pipes. A nervous current, having its source at a sensory point, cannot help going, except when stopped here or there by permanent check valves, thru the whole network of conductors, toward all the motor points.

But the intensity of the current, in a real nervous system with its innumerable ramifications, must vary enormously in the various neurons over which it distributes itself. And the intensity with which its energy passes out of the nervous system at the motor points, must likewise vary enormously. Our simple design with only three levels of connection can nevertheless illustrate this difference of intensity.

Imagine that the stimulus is applied at S_b. The rule to be followed for the computation of the distribution of the excitation is a double one. First, from any division point count the units of resistance thru which the excitation travels in "series" (without "shunts") until it reaches the next division point.—Second rule: add to this number the total resistance of all the shunted branches leading the current from the latter division point on and out of the entire system.—In working out the second rule you may have to re-apply, perhaps many times, both the first and the second.

From S_b to S_b^1 there is no division at all. Our computation therefore begins only at the latter point.

Two questions:

I. Resistance from S_b^1 to the right and out equals—?
II. Resistance from S_b^1 upwards and out equals—?

Question 1 is easily answered. The answer is 2. From S_b^1 upwards we apply our rules. We count 1 until we reach another division point in the figure, S_{bc}^2. Then we have two more questions:

III. Resistance from S_{bc}^2 to the right and out equals—?
IV. Resistance from S_{bc}^2 upwards and out equals—?

From this point to the right we count 1 until we reach another division point. Then we have two more questions: V. Resistance from M^2_{bc} right down and out equals—?
VI. Resistance from M^2_{bc} left down and out equals—?

Questions V and VI are easily answered. In each case the answer is 2, since we reach either M_b or M_c over two units of length, two units of resistance.

The total resistance of these last two shunted branches must now be found. For this purpose we take the reciprocal values of these resistances. The reciprocals of the resistances indicate the conductivities or flux values. We add these reciprocals together. Then we take the reciprocal of the sum. And this is the total resistance of the shunted branches. Why?

A simple consideration will show the reason for this procedure. Think of the passage of an audience in leaving a theater being obstructed by the smallness of the number and the small size of the doors. Giving each door a certain resistance value, we can not add these values together and call the sum the total resistance. That would lead to the absurdity of: the more doors, the more resistance,—and out of a chautauqua tent, being all doors, the audience could not get out at all, the resistance (obstruction by doors) being so great! Of course, such a procedure in computing is wrong.

But we can add the conductivities, the number of people getting thru every door in a unit of time. The greater this total, the less the total resistance of the doors. That is, the reciprocal value of the total flux, of the total conductivity, of the sum of the conductivities, gives us the total resistance.

The answer to questions V and VI was 2 in each case. The reciprocals are $\frac{1}{2}$ and $\frac{1}{2}$. The sum of these is 1. The

reciprocal of 1 is 1. That is, the resistance of all the shunted paths from M^2_{bc} out of the system is 1.

This leads us back to question III. The resistance from S^2_{bc} to the next division point, M^2_{bc}, was 1, and from this point on and out 1 more. So the answer to question III is 2.

Question IV refers to the path from S^2_{bc} upwards and out. Going upwards we counted 2 to the next division point, M^3_{abc}. And we have two more questions:

VII. Resistance from M^3_{abc} right down and out equals—?
VIII. Resistance from M^3_{abc} left down and out equals—?

Question VII is easily answered. Down to the right we count 1 until we reach the next division point. From this point out we encounter over all shunted paths 1 unit more, as computed above. The answer is the same as to question III, that is, 2.

The answer to question VIII is still more easily found. It is 3, because we count 3 units until we get out of the system, without finding any shunts, at the motor point M_a.

We now take the reciprocals of the answers to questions VII and VIII. These reciprocals are $\frac{1}{2}$ and $\frac{1}{3}$. Their sum is $\frac{5}{6}$. The reciprocal of this sum is $\frac{6}{5}$.

Question IV demanded that we take this sum, $\frac{6}{5}$, and add it to 2. Two units of resistance from S^2_{bc} to M^3_{abc}, and $\frac{6}{5}$ more, result in a total of $\frac{16}{5}$, which is the answer to question IV.

The answer to question III was 2. The answer to question IV was $\frac{16}{5}$. The reciprocals are $\frac{1}{2}$ and $\frac{5}{16}$. The sum of them is $\frac{13}{16}$, and the reciprocal of the sum is $\frac{16}{13}$.

This value we must add to the resistance unit 1 in order to answer question II. The answer to question II is therefore $\frac{13}{13}$ plus $\frac{16}{13}$, or $\frac{29}{13}$.

The answer to question I was 2; and to question II, as just found, $\frac{29}{13}$. At the first division point we thus find a resistance of 2 meeting the stream of the excitation toward the right; and a resistance of $\frac{29}{13}$ meeting the stream of the excitation upwards.

The flux upwards is indicated by the reciprocal $\frac{13}{29}$, and the flux to the right by the reciprocal $\frac{1}{2}$. Using common denominators we conclude that the flux toward the right is indicated by $\frac{29}{58}$, and the flux upwards by $\frac{26}{58}$.

Now, the denominator in no way concerns us. We are not interested in knowing what kind of units the flux units are. We are interested only in the relative numbers of the flux units, that is, in the numerators of the fractions having a common denominator. It will make no difference to us (interested only in the division, the manner of distribution, of the total flux) whether the units are barrels, gallons, quarts, fifty-eighths, cubic centimeters, or what not.

We now know that, for every 29 units going to the right, 26 units go upwards at this first division point. We naturally choose as the total number of units which we imagine to enter at the point of stimulation, the sum of the 29 and the 26 units, that is, 55 units. No smaller or larger number is equally convenient. These values we write in our figure in the proper places, 55, 29 and 26. Look at the figure, and you find them there.

The 26 units divide at the next division point in accordance with the answers to questions III and IV. The resistance to the right is 2, upwards $\frac{16}{5}$. The flux to the right is indicated by $\frac{1}{2}$, that upwards by $\frac{5}{16}$. In common denominators $\frac{8}{16}$ and $\frac{5}{16}$. That is, for every 8 units going to the right, 5 units go upwards. If of 13 units 8 go to the right and 5 upwards, then of the 26 to be divided 16 go to the right and 10 upwards. These values 16 and 10 we write in our figure in the proper places.

The ten units of excitation go one neuron upwards, then one neuron to the right, and divide here in accordance with the answers to questions VII and VIII. The resistance right down is 2, the resistance left down is 3. The reciprocals are $\frac{1}{2}$ and $\frac{1}{3}$. The common denominator is 6. That is, the flux right down is indicated by $\frac{3}{6}$; and the flux left down is indicated by $\frac{2}{6}$. For every 3 units going right down 2 units of excitation go left down. The ten units in question are therefore distributed so that 6 go right down and 4 left down.

The latter 4 units pass out of the system at the motor point M_a without further division. We write the number 4 under this motor point in our figure.

The 6 units of flux going right down meet at the next lower nerve center 16 other units coming from the left, making here a total of 22. Half of them, 11, go to the right down and pass out of the system at the motor point M_c without further division. We write the number 11 under this motor point in our figure.

The other half of the 22 go to the left down and meet at the next lower nerve center 29 others, making a total of 40. These 40 pass out of the system at the motor point M_b, under which we write in our figure this number 40.

The addition of 4, 40 and 11 gives 55. The total number of flux units going out must be equal to the number going in. This is a check on the computation.

We now have the clearest possible conception of the manner in which the nervous system distributes an excitation, resulting from the application of a stimulus to a sensory point, during its flow toward the motor points of the body.

CHAPTER V

The Other-One Appears now Attentive, now Absent-Minded, now Inattentive.

There is a joke about a man standing on a busy street corner and obstructing the traffic. The traffic policeman approaches him and says: "Move on, sir." He receives the reply: "It's your move, sir."

The enthusiastic chess player, walking home, is still occupied with his own and his partner's possible moves. He is ready to make one of these moves on the real chess board, and also ready to ask his partner (anybody) to make such a move, altho the stimuli which he receives from the street traffic are normally not responded to either by a horizontal and specially directed hand movement or by the vocal action of requesting someone else to make a horizontal hand movement.

What do we call such an abnormal readiness to respond by a definitely limited class of actions to any kind of stimulation? A stimulus which is normally not responded to by a certain action should be called a stimulus "inadequate" to this reaction. What then do we call such a responsiveness to an inadequate stimulus? We call it popularly "absent-mindedness." And what is its cause within the nervous system?

Before answering the last question, some further illustrations are desirable. You meet a person on the street who knows you well. You expect him to respond to the stimulus of your appearance by an adequate action. You observe,

however, that while passing you he looks you over from head to foot without saying anything or doing anything which could be called recognition or salute. That he wishes to offend you, to snub you, is improbable. He is "absent-minded." To the action of measuring by the eye, or of staring, the fortuitous sight of an acquaintance on the street cannot be regarded as an adequate stimulus.

A naturalist on the lake shore picks up things, examines them, and throws them away. He catches a frog in a net and takes him in his left hand. With his right hand he takes out his watch. After a little while he puts the frog in his vest pocket and drops his watch on the ground. To neither of these actions did the one or the other hand receive an adequate stimulus. The naturalist, we say, is "absent-minded." What goes on in his nervous system?

There is a widely distributed stream of excitation in the nervous system. It comes probably from many sensory points and obviously goes with the greatest intensity of flux in the direction of the motor point where the reaction is observed. The reaction seems unusual. That is, this flux ordinarily does not take this direction. If it nevertheless goes there, a temporary influence must have changed the conductivities—in favor of this motor point.

In the three illustrative examples of absent-mindedness the nature of this temporary influence appears clear enough. If we make the necessary inquiry we find that the chess enthusiast is not returning from a two hours sitting in a dentist's chair, but from a championship game. My friend who gave me the cold looks, is not returning from a social affair of the college faculty, but from a discussion in the anthropology research club. And the naturalist has not spent the last hour in repairing watches, but in picking things up from the ground, examining them, and throwing them away.

It seems that, when a current, coming now hence, now thence, for an hour or two hours (or even for a few minutes only) has taken the direction in accordance with the least resistance toward a certain motor outlet, during this time the resistances of the paths leading to this motor outlet have grown still less.

One can see under the microscope, under certain favorable conditions, that the small branches, the dendrites, of living nerve cells stretch themselves out or recede, like the branches formed by an amoeba. If this has a functional significance in the living body, it may be accepted as the only explanation or one of the explanations, and it seems to be actually the most plausible explanation of the fact of "absent-mindedness."

The current passes thru a certain synapse, as we have already called this region where the dendrites of one neuron surround the end of another neuron. The prolonged passage of the nervous current may be regarded as a sufficient cause for the stretching, lengthening, of the dendrites. The resistance of the path in the region of the synapse may thus be reduced by "improving the contact."

The natural consequence is that these sensory points which previously could send only a small amount of their excitation in this direction, can send a larger, possibly their largest fraction, to this motor point. The result is a local reaction where we did not expect it, guiding our expectation by our knowledge of the "situation" and of the customary reactions. A situation is the sum of all the stimuli of the moment. We knew the situation to be inadequate.

We are here attributing to the synapse a second function. In a previous chapter we regarded it as highly probable that the synapse region functions as a check valve. We now regard it as probable that the synapse has this second function,

—of reducing its own resistance, and of reducing thereby the resistance of a whole path, after this path has given somewhat prolonged passage to a nervous current thru this synapse.

How long must a current pass, before the reduction of resistance just spoken of becomes noticeable? After some hours it can be very conspicuous, as in our examples above. But even a few minutes may show a strong enough effect. Every student knows how difficult it is during the first few minutes to follow the trend of thought of his instructor, if another course has occupied the student during the preceding period. We may call the student "absent-minded" or we may call him "preoccupied." It means the same. After a few minutes the difficulty vanishes, and he becomes "absent-minded" in a new direction desired by the new teacher. The effect on the synapse, then, seems to make its first appearance already after a few minutes.

The experienced teacher gives the student a chance to "warm up" at the beginning of the period. Athletes, too, take warming up exercises for a few minutes just before a contest. The valuable effect of reducing the nervous resistances in the desired direction is much greater to them than the undesirable effect of tiring a little the muscles needed for the contest. (This statement does not deny that there may also be advantageous changes in the muscles themselves during the warming up excercises.) After half a minute the original difficulty of doing the new work in the class room or elsewhere may already appear considerably reduced. With the continuance of the current the effect grows steadily. After an hour or two the effect may become quite surprising, as in the above examples.

The effect would be more ordinary, less surprising, if its cause were of more common occurrence than it is. As

a matter of fact, being busily occupied in the same manner for an hour or two is a phenomenon which is relatively infrequent among ordinary people. (Compare, however, the next paragraph.) For many reasons, too numerous and too varied to mention here, people rarely choose to be occupied for hours by the same kind of strenuous life. "Let's do something else now," every few minutes, is not only the rule of life with children, but also with grown people, unless some outside force like school discipline, army discipline, or business discipline supersedes the instinct of the ordinary being.

But the factory worker is not absent-minded when he walks home. Does he not perform the same movements for eight hours? And yet nobody would choose him as a sample of absent-mindedness. He does not appear "preoccupied" when he leaves the factory. The reason why he does not show this effect can hardly be sought in any other fact than that his work depends mainly on lower nerve centers. There is a differentiation between the nervous tissue making up the lower and the higher centers. Many reasons, pharmacological experience for example, favor this assumption. Drugs do not seem to affect the lower and higher centers equally. Neither does work—that is, the passing of nervous currents—seem to affect them equally. The routine work of a factory is not likely to involve very high centers of the nervous system. That seems to be the reason why it does not result in "preoccupation," in "absent-mindedness." The synapses seem to be the more susceptible to the influence of a current the higher the nerve centers in which they are located. Only there, in the high centers, do the dendrites seem to stretch out or recede appreciably, according as a current has passed thru them or no current has passed thru them, during so much time.

It goes without saying, altho we have just said it, that the synapse increases its resistance by, slowly and to a certain limit, withdrawing its dendrites when no current passes thru them. The "absent-mindedness," we know, gradually disappears, in some minutes or in some hours, especially during a period of normal sleep over night.

The Other-One's behavior affects our life for one or the other of two opposite reasons. The Other-One may vitally interest us because he does something. The Other-One may vitally interest us because he does not do a certain thing. After having obtained a clear conception of the distribution of a nervous current, in the preceding chapter, we can see a positive, affirmative, aspect in both cases, in the Other-One's action as well as in his failure to act as we expected. We have learned to think of any single nervous current as passing out strongly at one motor point, X, and weakly at all others. In such a case we report (for example, to a newspaper, or to a friend) that the Other-One responded to the stimulus by a local reaction at X (some of his limbs). But we would be equally justified in reporting that the Other-One's local reaction at Y (another limb) did not occur; or that the Other-One's local reaction at Z (a further limb) did not occur. For example, after giving a newsboy a quarter for his newspaper and refusing the change, we may report that he said "Thank you." But we can also quite correctly and truthfully report: "He did not stand on his head." Especially correct would this latter report be, if we had been asked by anybody—say a lawyer in the court room—whether the boy stood on his head.

The affirmative aspect of the latter case, in terms of nervous currents, would be this: "One of the smaller fractions of the nervous currents went to the muscles which turn a boy from his feet upon his head." This affirmative state-

ment implies that this local action did not take place; that these muscles may have contracted a little; but that other muscular contractions were overwhelmingly strong.

If a recent influence during some minutes or hours has brought about a change of resistances in the synapses such that the largest fraction of the nervous current goes to these muscles, then the boy will stand on his head without an adequately stimulating situation. Almost any stimulus will then serve this end.

For example, he may have stood on his head much during the preceding hour, while attending a rehearsal at a circus where he occasionally is engaged as a clown. We later on the street give him a quarter, and he—"absently mindedly" —now stands on his head.

It helps us greatly in studying and comprehending the Other-One's life if we always remember that every form of behavior has both an affirmative and a negative aspect. There is always a response, in normal and waking life, to every stimulus; negativeness of response then does not consist in nothing, but in something that is not the expected thing. In "absent-mindedness" the affirmative aspect refers to the fact that the largest of all the fractions of the single nervous current passes out of the system at a particular motor point. The negative aspect refers to the (also affirmative) fact that at any particular other motor point in which an outsider may be interested a minor fraction of the current passes out.

The traffic policeman expects the man to walk. This expected response remains negative. Instead of it there is the positive response of strange talk.

I expect my acquaintance to say: "How are you this morning?" Instead of that he silently looks me over.

We expect the naturalist to put his watch in his pocket. Instead of that he drops it on the ground.

In these cases we had to consider only a single current at a time. A similar statement to that made above about an affirmative and a negative aspect of one and the same event is to be made when we have two or more currents. This leads us from the discussion of "preoccupation" to that of a different phase of the Other-One's life.

By a single current we meant a current coming from one sensory point. Of course, this sensory point may actually be something so complex as "the eye," including not only thousands of sensitive cells, but eve both eyes.

If there are two currents to be considered, if two sensory points are imagined to be stimulated, it can be regarded as virtually impossible that the two excitations are of exactly the same intensity.

The affirmative aspect of the event then is this. Most of the current from the sensory point A passes out at the motor point X; and this outflow is stronger than that at the motor point Y, where most of the current from the sensory point B passes out.

The negative aspect of the same event is this. Most of the current from the sensory point B passes out at the motor point Y; and this outflow is weaker than that at the motor point X, where most of the current from the sensory point A passes out.

But in the Other-One's real affairs is this negative aspect negative enough to suit Nature's needs? A concrete example will make this question clearer.

If the Other-One is a college student of the Fiji Islands sitting under a cocoa palm before a monkey and a college professor, these two performing simultaneously before the student, can the newspaper reporter truthfully report to his readers that the muscular reactions called forth in the audience by the performance of the professor were negli-

gible, not worth mentioning? He probably can so report; but still more comforting to the Islanders and especially to their Board of Education would be his report that in the strictest sense there were no such muscular reactions, so that no harm could come to Nature's intentions from having in every monkey circus also an intruding professor lecturing from a pulpit on such a senseless thing as algebra.

Nature, uninterfered with by the intentions and inventions of civilized mankind, ought, if she could, to object to such wasteful endeavors as algebra lectures, considering the educational advantages of a monkey performance, from which the student can learn the essential features of skill necessary for getting cocoa nuts.

The example probably suffices to make it clear that the builder of the nervous system ought to provide for some means by which in the given case the second stimulus (the professor) and many further stimuli also of less importance than the monkey can be made entirely innocuous.

Nature has indeed made such a provision. The stimuli causing the weaker excitations are made entirely innocuous by being entirely eaten up, so to speak, by the stronger ones. Nature gets rid of the wasteful influence on the students' life by the algebra professor. Nature does this by forcing him to "compete." Now, what does it mean to "force a stimulus to compete with another stimulus?" An example of things which do not compete will make clear what competing things are.

A ship, driven by several things—the wind, the current, the screw—, follows all of them simultaneously. We can find its place on the map after an hour thus: we draw first a line thru which it would move during an hour driven only by the wind; from the end point we draw another line thru which it would move on the map during an hour driven

only by the current; from the end point we now draw a third line thru which it would move during an hour driven only by the propeller. The final actual result is the same. At the end point of the third line the ship is actually found after an hour; only it did not move to this point over the zig-zag line we drew, but over a straight line called the resultant. But, let us say it again, the final result is the same. The place which the ship reaches after one hour under the influence of three forces is exactly the same as that which it would have reached if one of these forces had acted for one hour, the second force alone for a second hour, and the third force alone for a third hour. This fact we express by saying that those things which are studied in physics, whenever they are under the influence of several forces, are governed by the law of the resultant.

The Other-One's mode of response is entirely different from that of the ship. If he attends for one hour a monkey's performance and for another hour an algebra teacher's performance and then is given an examination on what happened during the two hours, the result is by no means the same as that of an examination given at the end of one hour, during which both the monkey and the professor performed simultaneously.

We never speak of the competition of the forces of physics. Do not think of positive and negative forces in physics as competing. Never is one of them selected and the other one neglected. They are added together, and thus, by addition, the resultant is found.

But we may speak of the competition of the forces which act on the Other-One. We may in other cases speak of their resultant. That depends on circumstances within the network of the nervous system.

When we speak of competition, the selective effect of the Other-One's nervous system on the situation, on the totality of the stimuli, is popularly called "attention." We say that the college class gives attention, or that it cannot help giving attention, to the monkey performing simultaneously with the professor; and that the college class does not give attention to the professor during the monkey's performance.

Nothing is more ordinary in the Other-One's life than events of this kind. He looks up, and many things are projected upon his retina. But few succeed in being "attended to," in being reacted upon by his muscles. When the Other-One reads a book, he cannot accomplish everything that we wish he could. He gives attention to the meaning and fails to notice the beauty of style. He is engaged to look for typographical errors, and we find with regret that he does not notice a lack of logical connection between two sentences. For each purpose a new reading is necessary. We do not expect him--because we have found that we cannot expect him—to write an essay while a piano is being played on one side and a crying baby occupies the other side of his room. Ask him to solve a problem in arithmetic, in order to save time, while he is performing a gymnasium feat. He brings the reply that he cannot do it. A student tries to prepare a lesson while walking at a rapid gait. He does not succeed. The difficulty of reading during the motion of walking is not the main obstacle, for he succeeds fairly while being shaken just as badly in an omnibus. It is his own action in walking which competes with every other action. In the omnibus there is little such competing action. The Other-One listens to music, and we see him shut his eyes, excluding thus the competition of the visual stimuli. The examples could be continued indefinitely.

According to the popular view, attention is an independent force, a steersman who stands at the helm, so to speak,

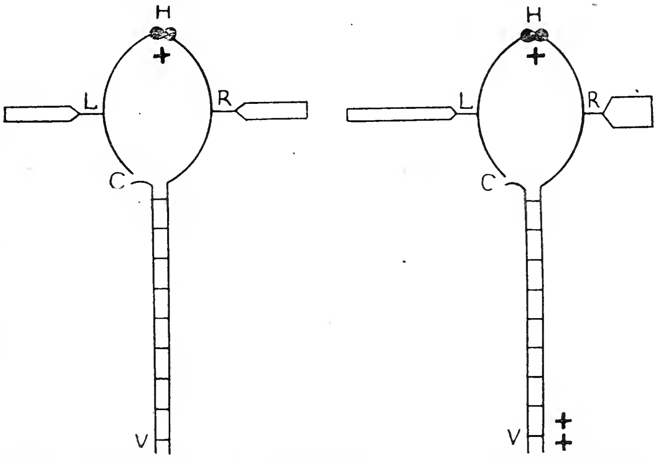
and changes the ship's course arbitrarily or by prearrangement. This is pure mythology. The enhancement and impairment of nervous currents, which are the concrete facts behind the abstract terms "attention and inattention," are not the results of an independent force, but simply the effects of peculiar quantitative relations existing between these nervous currents. Why these quantitative relations of the nervous currents have on the muscular activities usually the effect, not of a "resultant," that is, of addition, but of "competition," that is, of selection, must now be made clear and plausible.

An experiment made first some years ago by the biologist Uexkuell on a nerve-muscle preparation is so instructive, clarifies our thought by the simplicity of its details so much, that we must not omit it here. Our double figure shows, right as well as left, between the letters V and H the same part of the nervous system of a worm. V is the ventral cord, which corresponds in a worm to the spinal cord in a vertebrate animal. In the head region the ventral cord splits and surrounds the mouth opening, then unites again in the front region of the head and forms here the head ganglion, H. On the left and right sides of the head are muscles, called L and R in the figure. The essential feature of the nerve-muscle preparation is the cutting of the left branch of the head division of the nervous system near the ventral cord, at the point marked C in the figure.

The experiment consists of two phases, the results of which are to be compared. The results are shown separately in the drawing on the left and in the drawing on the right. On the left the head ganglion alone is stimulated. This is indicated by the cross under it. The result on the muscles is exactly what anybody would expect. Both muscles respond equally by contraction, since they are reached by the

excitation coming from the head ganglion with equal intensity.

In the other phase of the experiment, in the drawing on the right of the figure, the head ganglion is stimulated as before. But at the same time the ventral cord is stimulated much more strongly than the head ganglion. This is indicated in the figure by the double cross at the point V. The result on the muscles is not an additive, but a selective result. The left muscle, previously just like the right muscle



DEFLECTION OF A CURRENT IN A NERVE-MUSCLE PREPARATION.

somewhat contracted, now completely relaxes. Obviously none of the excitation from H can pass out at L any more.

None of the excitation from V can pass out at L, of course, because of the gap at C. All of the excitation from V as well as from H now obviously passes out at R. Indeed the right muscle in this case is greatly contracted, quite contrasting with the relaxed left muscle.

To the student inexperienced in the phenomena of the natural sciences this is very surprising, almost mysterious. To him who is familar with the natural sciences and their history this not so surprising. It is merely an additional

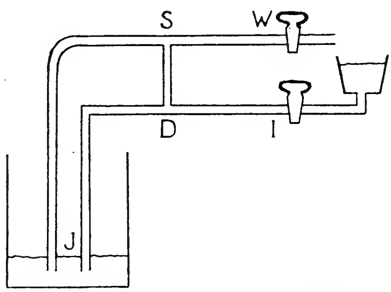
interesting example of the fact that—if we are clever enough to see the law and order reigning in the apparent chaos—we find everywhere, say, in electricity, what we find in mechanics; we find in chemistry what we find in mechanics; we find in biology what we find in mechanics; and so forth: that is, that the laws of matter and motion are the fundamental laws of all Nature, only growing more complex as we pass from the field strictly called mechanics to those other natural sciences. This experiment is a beautiful illustration fit to be incorporated in any History of General Science.

A well known law of mechanics states that the pressure in a moving fluid (liquid or gas) is the less the greater the velocity. If the velocity becomes zero, the pressure reaches a maximum. And a moving fluid therefore attracts, by suction, another fluid which moves with a lesser velocity down to zero velocity. (The positive or negative sign of the velocity is here irrelevant.)

This principle of suction by a current of high velocity is rarely thought of; yet it is much used by those who do not think of it. Many are the various sprayers for perfumes or medicated substances. The farmer sprays in essentially the same manner his potato plants, cabbages, orchard trees, and so forth. The attracting current is in these cases a current of air. The physicist in his laboratory exhausts the air from a glass bell, the chemist from the space under a filter by means of a current of water served by the ordinary water supply system. The city dweller often by such a current of water pumps the river water from his flooded basement. In all these cases a current of small or zero velocity is attracted by a current of greater velocity, with which, of course, it must be somehow in contact.

One can demonstrate this principle of the jet pump in a special form in which its analogy to the nervous function under consideration is clearly brought out. Our figure shows the simple apparatus needed. Two parallel glass tubes lead, one from the water supply system, W, the other from a supply of ink, I, that is, colored water. Both tubes dip into the jar or other reception tank, J, for the purpose of keeping air bubbles from entering the glass tubes. The tubes communicate with each other thru another tube between S, the suction point, and D, the deflection point.

By means of the cocks at W and I the relative rate of flow between W and J and between I and J can easily be so adjusted that the communicating tube fills with ink up



DEFLECTION OF A HYDRAULIC CURRENT.

to the middle between S and D, and with water down to this middle point; and that an undisturbed current of clear water flows from W to J, and an undisturbed current of red ink from I to J. Now turn the cock W so that the flow of water increases slightly,—and you see the ink rise in DS and give a rose color to the water from S to J. But the color of the ink from D down to J is still the same.

Now turn the cock W a little further in the same way,—and all the ink coming from I turns at D abruptly up to S where it joins the water. No ink at all passes now from D to the left. This can be made very obvious by letting some of

the water from the jar be sucked up as far as D. Then one sees red ink flowing from I to D and from D to S; but from D to the left, where it formerly went, one sees water standing still. The experiment in spite, or perhaps because, of its simplicity is apt to cause a great deal of astonishment to those who never before observed anything like it.

If we compare Uexkuell's worm with this experiment, we find that the conditions are the same. The current from H to L in the worm corresponds to the ink current from D to J. The current from V to R in the worm corresponds to the water current from S to J. The conductive tissue between H and R in the worm corresponds to the tube between D and S. In the worm, R is the suction point (S in the tubing) and H the deflection point (D in the tubing). All of the nervous current which tends to go from H to L is deflected in the direction HR; none of it is any longer permitted to pass out at L.

We recall now the case of the competition between the monkey and the professor. Each one causes a nervous current in the student sitting at their feet. For reasons which we need not discuss here the current caused by the monkey is the stronger current,—or we assume it to be the stronger current. Then the current caused by the professor is deflected from the course leading to its proper outlet, to the motor point corresponding, reflexly, to the sensory point stimulated. The student does not react to both the monkey and the professor,—strongly to the former, a little less to the latter. He may not even react to both the monkey and the professor,—vigorously to the former and faintly to the latter. He most probably reacts exclusively to the monkey. Attention, then, is deflection—partial or total—of a nervous current by another and stronger nervous current.

Now the question may be asked if nervous currents are currents of a material substance, comparable—at least by not too remote an analogy—to currents of fluids as we study them in mechanics. An excitation is undoubtedly a chemical substance which might be taken in a spoon, if such enormous quantities of it as a spoonful could be separated and collected.

Let us use this opportunity to tell briefly what physical processes have actually been found by the neurologists to go on in the nervous conductors. Whenever anything of the nature of an excitation occurs in a neuron, an electrical phenomenon is observed. But it is generally admitted that this electrical phenomenon is not the excitation itself. There is no such thing as an electrical insulation surrounding a neuron, which would enable an electrical current to pass along a neuron. And further, the velocity with which the excitation is conducted is almost infinitely small when compared with the velocity of electricity in its conductor. During the time a nervous excitation is conducted one way and back through an elephant or other large animal, electricity can circle the globe. The electrical phenomenon must be, therefore, a purely accidental accompaniment of the conduction of an excitation.

It is highly probable that the conduction of the excitation is a process of a chemical nature. The substance of a neuron, consisting of highly unstable organic compounds, must be well adapted to the conduction of chemical changes. It is also well known that the conduction of chemical changes frequently involves, as a by-product, so to speak, electrical phenomena. Indeed these electrical phenomena accompanying the conduction of chemical changes have been used technically and have become of the greatest industrial importance in the so-called accumulators or electrical storage batteries.

An accumulator is essentially a conducting fluid on the sides of which there are two related, yet different chemical substances, most commonly lead compounds. One of these substances has a tendency to take up a certain more elementary substance; the other has a tendency to give off this same elementary substance. The same elementary substance is one of the components of the conducting fluid. What happens is this: A stream of substance flows—or, whatever it may actually do, is imagined to flow—from one end of the conductor to the other, and this flow, the wandering of molecules or ions, as it is usually called, is accompanied by an electrical phenomenon. We are probably justified in regarding the conduction of an excitation through a neuron as, not identical with, but at least analogous to the wandering of ions through the conducting fluid—the electrolyte, to use the technical term—of a storage battery.

In the storage battery the electrical current is the thing we want, and the stream of ions is a mere by-product, hardly thought of by most people who use storage batteries. In the industrial process of electroplating the electrical current is the mere means without which we cannot work; but the stream of ions is the real end. We let the molecules of a gold salt, or silver salt, or nickel salt, wander under the push of the electrical current and carry the gold or other metal and distribute it over the thing to be plated. Thus in the industries we are sometimes more interested in the electrical current, sometimes more in the chemical current. In the function of the nervous system we must regard the chemical current as of fundamental importance.

A few rather technical remarks should be made here, just in order to avoid misunderstandings. In any fluid, at the moment when motion begins, a relief of tension passes thru the fluid. This tension "wave" has a definite velocity.

In the air we give the velocity of a tension wave the name of "the velocity of sound." The equivalent (or analogy) in nervous conduction of this velocity measures probably in the neighborhood of a hundred feet per second. It has no relation whatever to the hydraulic velocity difference of which we spoke as being responsible for the deflection of currents.

Further, the velocity with which an individual ion wanders thru its path, separating itself from one molecule and entering another, is an entirely different thing. That velocity is probably very small. Whatever it may measure, it has no relation, either, to the hydraulic velocity difference responsible for the deflection of currents.

But the "rate of flow" of the chemical substances, if it were measurable, would unquestionably prove to be the equivalent of the "velocity" on which the deflection effect in the nervous system depends. The rate of flow in the student's nervous system caused by the monkey in our example is greater than the rate of flow caused by the algebra professor.

From one misunderstandable term, that of "velocity," we must unfortunately turn to another one, that of "inhibition," before we can profitably proceed with the Psychology of the Other-One. The negative aspect of the "attention" process might well be called "inhibition" if this term did not so easily lead to confusion on account of being used by the physiologists in a special and different sense. When we observe that the Other-One reacts to the monkey, but does not react to the algebra professor, we may feel inclined to say that his reactions to the professor "are inhibited." But the physiologists do not mean that by inhibition.

They mean the fact that in certain cases a nervous current causes, positively, relaxation of a muscle and thus

counteracts the effect of another nervous current tending to cause in the same muscle contraction. It is a case of "algebraic addition." The physiologists speak of "inhibitory nerves" when they refer to nerves which bring about the effect of muscular relaxation. Since in the function of the inhibitory nerves we have addition and a resultant, not competition and a selection, it is better to leave the term "inhibition" altogether to the physiologists and use in psychology with reference to "attention" phenomena exclusively the term "deflection."

In life situations in which deflection is most conspicuous we usually say that the Other-One or an animal does something "instinctively." The student "instinctively" reacts to the monkey instead of to the professor. The boy "instinctively" continues to play ball instead of responding to his mother's dinner bell. The broody hen "instinctively" sits on her eggs instead of scratching in the dirt. The bird "instinctively" builds a nest instead of taking a pleasure excursion over the landscape with a song obbligato. We can without much difficulty represent "instinctive activities" by an architectural design of a nervous system. First let us see more definitely what the requirements are with which the architect has to comply.

In instinctive activities, that is, in activities which the usage of language thus designates, we rarely, if ever, can speak of a local response. It is always a case of concerted action. If our interpretation here of the spirit of the language is correct, if "instinct" implies also deflection, we have a combination of deflection with concertedness.

The purpose of a graph is always that of aiding our grasp, our memory. Let it serve this purpose here. For the graphical representation of an instinctive activity in the architectural design of a nervous system we probably

choose best the activity of an animal. In general, analysing and simplifying a complex event is easier there than in human life. We shall draw an architectural design for a bird's instinctive activity of nest building. For simplicity's sake we regard the concerted action as being nothing but simultaneous action of two motor points, the wings in flying and the bill in picking up, holding and dropping the building material.

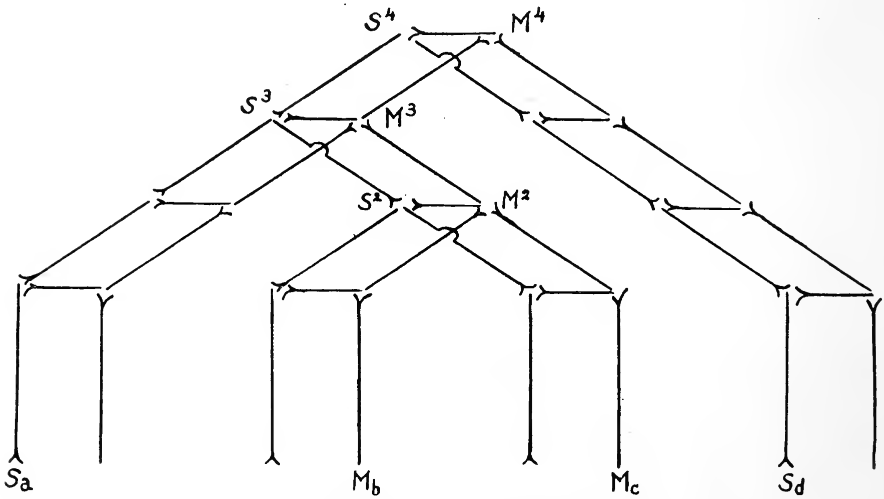
We restrict our discussion to the nest building activity of the female bird. Then we may assume for the drawing of our figure that one specific excitation (and no others, affecting also the male) is responsible for the concertedness of the actions of the bill and the wings. There must be a place ready to receive the eggs and capable of sheltering them. The nest must be built in advance of laying. It must be built (and is built only) when eggs are growing in the ovaries. We must assume that the growth processes in the ovaries act on a special sense organ as a stimulus. The resulting excitation we call the "specific excitation" of the instinctive activity of nest building.

In our figure, S_a represents the sensory point of the specific excitation. It is located probably in the ovaries themselves. The motor point corresponding and forming a reflex has not been given a mark in the figure because it does not concern us here. Only the absolutely essential points have been marked with letters. However, it might be suggested that it would represent the muscle fibers in the arteries supplying the ovaries, and that this reflex would regulate the blood supply so as to be commensurate to the necessities of the growth of the eggs.

The motor points M_b and M_c represent the muscles of the bili and the flying apparatus, which have to act in concert. The nerve center $S^2 M^2$ unites them. The sensory

points corresponding to these motor points do not concern us here and therefore are left unmarked in the figure. It might be suggested, however, that the reflexes of the bill and the wings depend on visual stimuli, the sight of the building material and the sight of the branch of the tree or shrub chosen as site of the nest.

The sensory point S_d represents all those innumerable sensory points whose excitations would better be deflected if nest building is to proceed efficiently, that is, properly



OVERFLOW AND DEFLECTION IN INSTINCTIVE ACTIVITY.

Sa—ovaries
Mb—bill muscles } of a bird.
Mc—wing muscles
Sd—irrelevant stimulations

and promptly. What the responses are, in life's ordinary language, called, does not matter. Any and all responses inessential or irrelevant to nest building ought to be prevented. Since we do not name them, the corresponding motor point has been left unmarked.

Summing up: the specific excitation, which comes from S_a, performs two services, that of insuring by way of the center S^3M^3 the concertedness of the actions at M_b and M_c

and that of deflecting by way of the center $S^4 M^4$ all currents coming from the bulk of the sense organs, S_d.

This leaves still one question. Why must the center over which the specific excitation deflects other excitations be higher than the center over which it reaches the motor points acting in concert? Answer: otherwise it would deflect also the currents of the concerted action, and there would be no nest building.

The currents of the concerted action must not be impaired, but enhanced. In order to express this in theoretical terms, it seems necessary to introduce the conception of "overflow."

This is a very abstract statement, in this paragraph; but it must be made. In electrical conductors the resistance rises with an increase of the flux, because the temperature rises with the flux unless there is special cooling. In nervous currents there is not probably any need of referring to any rise in temperature. But suppose that, just the same, the resistance is not constant, but rises with the flux; or, as we may say, the conductivity diminishes with an increase of the flux. Suppose further that the higher a nerve center, the more rapidly the conductivity of a conductor diminishes with the flux increase. Suppose that thus in the highest centers the conductivity is small quite out of proportion to the increase of the flux in any theoretically considered problem.

Then the highest centers will tend not to carry their share if there are any lower centers still available. This principle may popularly be called "overflow." Its assumption seems unavoidable, absolutely demanded by the facts. (Of course, this statement is of the nature of a revision of the computation which we made in the preceding chapter under the simplest possible theoretical assumptions.)

In our figure the dividing level between overflow and deflection is supposed to lie between the third and the fourth center. The overflow of the specific excitation does not reach higher than the third center. From the fourth center on, the deflection can then become effective.

Because of the necessary distinction between the effects of overflow and deflection, in any architectural design of the nervous system representing both overflow and deflection, the highest overflow center must be lower than the lowest deflection center.

It is then, of course, the Creator's business to make the difference in level between the highest overflow center and the lowest deflection center for each so-called "instinct" large enough,—safe for the proper execution of the performance. There are numerous observations, which we need not repeat here, of individual aberrations or perversities in the instinctive activities of animals as well as in those of mankind. There does not always seem to be a proper margin of safety in the construction of individual nervous systems.

Even a whole species of animals may become perverse. For example, the European cuckoo does not build a nest. The bird lays her eggs in the nests of other birds, generally much smaller, with the well known disastrous consequences for the hosts. But this leads us too far.

He who thinks for the first time of the deflection, in the nervous system, of a current by another current, may be more struck by the effect which to some extent this has on the deflecting, than by the effect which it has on the deflected, current. Why! Is not the deflecting current strengthened thereby?

At the first moment this may seem surprising. Do we pay, to what we are occupied with, more attention on account

of the little noises and the diffusedly lighted objects which usually surround us during our work. Then it ought to be advantageous for office clerks to typewrite their letters in an office noisy from the clicks of other machines, for masons to lay their bricks while a music band plays lively tunes in the neighborhood, for debaters to debate in a well illuminated auditorium where innumerable faces are in sight, for athletic teams to play their games in the noise and sunlight of the stadium. And indeed it is. Theory and practice agree. Sights and noises, to the extent that we pay no attention to them, far from being merely indifferent, are positively helpful.

Careful experiments have been made by psychologists on the effect of exclusion of the ordinary, diffused, noises of the day, and exclusion of the ordinary multiplicity of lights and sights, on ordinary school work. Even in the school room such exclusion of all but the adequate stimuli diminishes the normal rate of activity of the school children to the detriment of their scholarly progress.

There is no contradiction in the fact that the advanced scholar—let us think of Faust, the magician, in the theater scene—works better in a silent and almost dark room, or that midnight oil seems to help us in preparing for an examination. The advanced scholar, the thinker, for his progress needs to be, not only attentive, but also absent-minded, preoccupied. And noise and light would interfere with his preoccupation. But for the attention of ordinary busy folk the reduction of light and noise is indeed harmful. They are not preoccupied. And therefore they are exposed to the danger of a reduced rate of activity; to use a more striking term, to the danger of getting into a condition of boredom, sleepiness. That means the end of fruitful occupation. Every teacher knows it. A little

noise and a little glitter on the side do not distract, but help.

The college student who objects to a ray of sunshine coming thru the class room window to hit his nose and who lowers the shade, may honestly think that he is preparing himself for listening free from annoyance. Actually he is preparing himself for sleeping more soundly.

To take an extreme example, a very feeble-minded person, an idiot, can be easily put to sleep by merely placing him alone in a noiseless and fairly dark room.

We could not help using the word "attention" in various shades of meaning which the usage of language has given to it. To describe human life purely in purposely defined technical terms is yet impossible, altho it is the ideal toward which we strive. Those shades of meaning become still clearer if we use the negative form "inattention." The Other-One may be called—is actually called—inattentive in one or another of three different senses.

1. Deflection.—The school boy who plays with a knife under his desk is called inattentive by his teacher. The teacher knows that he is very attentive—to his knife. The wrong kind of attention, in the case of deflection, is from the social (educational) point of view inattention. He does not do his duty.

The psychologist speaks of attention, for there is a strong nervous flux. The boy is very active.

2. Preoccupation.—The school boy who writes down his birthday presents, instead of the copy given him by his writing teacher, is from the social (educational) point of view inattentive. He fails in his social duty of action.

From the psychologist's point of view he is neither attentive nor inattentive. That there is a certain stimulus to which he does not properly react, is to the psychologist an

accident. There are many other such stimuli. Why emphasize that one? The boy is somewhat active, but "absent-mindedly" active.

3. Sleepiness.—The school boy whose eyelids droop and whose head falls upon his chest is from the social (educational) point of view inattentive. He does not do his duty.

The psychologist, too, calls him inattentive, for there is hardly any nervous flux. He is very inactive.

That these shades of meaning, poorly understood, may have quite serious consequences in our social life, is obvious. The present writer recalls a case from his school days. One of his teachers, standing before the window, asked him suddenly if he was not inattentive. He was still looking at the blackboard, on which the teacher, two minutes ago, had written an important equation. He replied, quite honestly, that he was not inattentive. Thereupon the teacher, also quite honestly, called him a liar. Here let us end the story.

The cure for sleepiness is a wakeful environment. The cure for preoccupation is a more vigorous presentation of the proper stimuli. The cure for deflection is a strong discipline which orders the deflecting stimuli to be left at home. Speaking of a cure, we of course take sleepiness, preoccupation and deflection in the sense of evils, in the social sense of inattention.

But we must not forget that deflection and preoccupation, when they lead toward a social aim, and when, going hand in hand, they lead toward the same social aim with vigor and consistency, are the true mark of genius. Therefore the highest genius is a person of discipline—as all biographies prove,—for without discipline deflection and preoccupation would not go hand in hand. The undisciplined person might be a "Bohemian" genius, but not a real genius.

CHAPTER VI

THE OTHER-ONE VARIES HIS MODE OF REACTION GRADUALLY OR SUDDENLY: HE LEARNS AND WILLS.

A little girl had been fortunate enough never to have received any candy nor to have seen anybody eat candy. One afternoon a woman friend called on her mother and, just before leaving, gave the girl a piece of somewhat soft and sticky candy. When she had left, the little girl dropped the candy on the fire place and accompanied her action by the remark addressed to her mother: "That woman gave me dirt."

A few years later that same girl frequently boiled her own candy, pulled it, and ate it lustily. What had happened?

When she dropped the candy the woman gave her, a reflex functioned. A touch stimulus of a thing rather soft and sticky brings about a reflex stretching of the fingers, giving the candy a chance to follow the law of gravitation, and also a stretching of the arm, giving the thing a positive aid on its way downward. But there came a time in later years when an injudicious person, on a similar occasion, took the candy out of the girl's fingers, before it had time to fall on the ground, and put it in the girl's mouth. It quickly began to dissolve and to act as a taste stimulus, and the reflex action resulting was a bending of many outlying "limbs" such as the fingers, arms, lips, tongue. And the candy, instead of falling on the ground, was pushed down the esophagus.

After that, when a piece of candy touched the girl's fingers, the fingers bent and held it, the arm bent and carried it toward the mouth, the lips bent and pushed it in,

and the tongue bent and pushed it down the esophagus. The reflex "taste-bending" had been mixed up with the reflex "touch-stretching." Something new had resulted, based on the nervous function "touch-bending." This nervous function, starting from a soft, sticky touch and resulting in a bending of limbs, is not a reflex. If it is not a reflex, what is it?

There are some psychologists who like to call something like our "touch-bending" a conditioned reflex. "Bending" occurs after "taste" as a reflex movement unconditionally; but after "touch" it occurs only "under condition" that the "taste-bending" reflex has been appealed to.

Inasmuch as "conditioned reflex" is a clumsy term and could be tolerated only if we had no better term, we shall not use it. No serious objection can be raised against the old-fashioned term "habit." Literally habit means a garment; then also a form of life, a mode of conduct, not naturally grown out from the body, but put on it from without, so to speak. As in our example, habit has always in the usage of language signified the exchange of components among two stimulus-reaction functions, except to loose thinkers to whom it may never have meant anything definite. If any student has the habit of thinking of a habit of conduct as a sheer mystery, then he should be advised to clarify his thought by using the term "conditioned reflex," which would constantly remind him of the fact that no habit can be put on an animal except one whose sense function and motor function have already, in other combinations, been given to the animal by Nature. He who realizes this fact that "habits" cannot be created out of nothing, but only out of "reflexes," need not use the inconveniently long expression "conditioned reflexes."

Purely logically, we should expect three classes of habits, because two reflexes can be thought of as becoming so re-

lated that the motor function of one either (1) replaces the motor function of the other, or (2) is added to the motor function of the other, or (3) is subtracted from it.

As a typical example of the third class can serve any graceful action which develops out of an awkward action. An action is called awkward when it contains superfluous muscular responses. The young scholar, or the illiterate person who late in life attempts to write, writes, so to speak, with his arms, his legs, and even his head,—not to mention the subdivisions of these limbs, the tongue, for example, which can sometimes be observed to "try to help."

Or, a person not accustomed to appear before audiences, walks awkwardly across the stage. Making superfluous muscular responses, as common in babyhood, he "stumbles over his own feet."

When the Other-One, in his first attempts at performing an action as difficult as writing or walking, makes more movements than are necessary, we call him awkward. After he has "learned" to omit the unnecessary movements, after they have been subtracted from the response, we either say simply that he "does" the thing, that he writes, that he walks, and so forth, or we say, in certain situations of life, that he does the thing "gracefully."

The variation of the total nervous path might be given a special name in this case; perhaps the name of "motor condensation." The giving of the name serves no other purpose than that of pointing out that there lies here a great field for future research. If we call it "condensation," we have in mind the fact that the nervous path, instead of spreading out while it proceeds to the motor outlets into many channels like a river with "a thousand islands," is condensed into one definite narrow location. In what manner such a "motor condensation" develops in the Other-One's nervous system, is as yet only a problem, not a known fact.

The second class of learning consists, we said, in the motor function of one reflex being added to the motor function of another. Innumerable examples could be given from the Other-One's life. Sometimes a negative example illustrates most strikingly. A common deficiency of the Other-One, in not having learned to add a certain muscular action, is his often observed stooping, the failure of the muscles throwing his shoulders back and keeping his head erect while he is walking or standing or sitting engaged in some special work.

Originally, in such a case of learning, the stimulation must of course be complex in order to make the response include the feature to be added. For example, we may in every situation have to "remind" the Other-One that he must straighten himself. Later the same complex response is called out by a simplified stimulation. The reminder in our example is left off. The nervous activity then becomes similar to an "instinctive" activity, for a complex reaction in response to a simple stimulation is, as we have seen, characteristic of an instinct. In order to have a brief term for this kind of a variation of the nervous path, let us call it "sensory condensation," thus referring to the fact that at the sensory end of the system of nervous conductors the flux (when represented reversely in a diagram) no longer looks like spreading broadly, but like being condensed in a narrow channel.

An example, rather complex in all its aspects, but very familiar and therefore well illustrating our case, is the following. In playing a certain piece of music on the piano, at a particular place in the music each one of several fingers has to perform a definite movement,—what movement, is indicated by as many notes as there are fingers to move. The beginner, in order to strike the correct chord, looks at every note. But after some time of practice, we observe

that he plays exactly the same complicated chord even when some of the notes, without his knowledge, have been erased or changed by us. Obviously these notes are no longer needed for the response, and a simpler stimulation now brings about the same complex motor response.

Typewriting, reading, proofreading, weaving, attending to any machine,—any kind of skillful activity can illustrate this same kind of variation of the nervous path. The complex activity is ultimately called forth by a part of the original stimulation; sometimes to the detriment of the subject, as when a proofreader overlooks a typographical error, reading the whole word altho not all of the word is there to act on his eyes.

The manner in which all this develops in the nervous system is no better known in the case of sensory condensation than in the case of motor condensation. Here we have at present some of the greatest and most pressing research problems of psychology.

Going back now to the first of those classes of habits which we distinguished on purely logical grounds, we should give further examples where the motor function of one reflex replaces the motor function of another. We should think of further examples for the following reason if for no other. Students sometimes believe—and even psychologists have believed—that the relation of "antagonistic muscles" plays a role in the learning process. It is true that a habit often consists in replacing a motor function by that of its antagonistic motor function. For instance, in a certain habit of avoiding pain, contraction of the extensor muscles of the right arm is replaced by contraction of the flexor muscles of the same arm. But this is a fortuitous circumstance. The muscular reactions in the next example are not antagonistic.

A horse, when it hears the crack of the whip, reflexly pricks up its ears. Soon afterwards the whip may touch its skin. This cutaneous stimulus calls forth a forward locomotion, a "start." The start thus produced is a reflex. Later the crack of the whip stimulating the ear calls forth the forward locomotion. That then is a habit.

A baby sees a candle flame. Reflexly he stretches his finger toward the flame. The heat begins to act on the finger; and the arm is withdrawn. Sight-stretching is one reflex; heat-bending is the other reflex; sight-bending is the habit. The motor functions are again antagonistic; but that is fortuitous. What is different in this case from the other two examples of "replacement" is the fact that here the two nervous currents of the reflexes can hardly help being simultaneous for a considerable time. In the other two examples the currents succeeded each other.

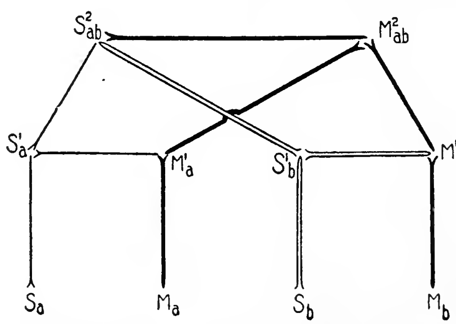
Let us take an example of habit formation from the college recitation room. The professor pronounces a question. This is a stimulus acting on the student's ear. The student responds by saying "I don't know." Now, this function "sound-speech" in this case is no reflex. The nervous functions which play the larger role in the class room are naturally not reflexes, but habits which have resulted from the student's reflexes during many years of previous schooling. But we can here regard the response "I don't know" as if it were a reflex response. The manner in which habits are derived from other habits is exactly the same as that in which habits are derived from reflexes.

After this answer of the student, the professor in the natural course of events produces the second stimulus by pronouncing the statement which makes the right answer to the previous question. And the student, if he is the right kind of student, imitates this statement, not necessarily aloud, but by speaking to himself, or by writing. The case

is exactly the same as if we had two reflexes "question-negative answer" and "statement-positive answer." The resulting habit is "question-positive answer." In this case the two original nervous currents are again successive as in the first two examples.

In the case of a replacement of one motor function by another it is as in the other two classes of habits a pressing problem of present and future research to know what really happens in the nervous system. The case of replacement of a motor function appears simpler—it is doubtful if it actually is simpler—than either of the cases of condensation of the nervous path. Therefore we might at least here make a conjecture by the aid of a diagram showing the two reflexes. If it does not fully explain the formation of the habit, at least it will suggest an approach to the solution of the problem to the student who wishes to become an investigator. It will show him, too, how much knowledge of physics, chemistry, and biology he will need for that purpose.

In the figure "Learning, a Function of two Reflexes Combined" let us see what neurons conduct the excitation



LEARNING, A FUNCTION OF TWO REFLEXES COMBINED.

whenever S_b is alone stimulated. They are, eight in number, marked in "broad" lines, partly black, partly double. On the other hand, the neurons which function when S_a

alone is stimulated, are all marked in "single" lines, partly fine, partly black.

Now, it is quite indispensable, from all we know of the Other-One's life, to assume that a flux passing thru a neuron reduces its resistance (not much at once, but still reduces its resistance), and that this reduction very, very gradually disappears, but even in many years not entirely. This reduction of resistance, that is, increase of conductivity, is therefore very different from that which we have attributed to an improved contact in the synapses, and which can generally and normally by proper methods be caused to be completely gone in a few minutes. "Preoccupation" is something entirely different from habit, at least in a normal being,—in certain neuroses, abnormalities, which we shall discuss in a later chapter, the distinction may become difficult. The reduction of resistance with which we are at present concerned is clearly a change in the permanent chemical properties of the neuron.

We said that when S_b is stimulated, the excitation takes its path over the black and the double lines. A moment ago, let us assume, S_a was stimulated, and the excitation took its path over the black and the fine lines. Therefore, when the excitation coming from S_b reduces the resistance in all the neurons thru which it passes, the resistance of the neurons drawn in black lines not merely begins to be reduced, but is further reduced. In the total system of the figure the neurons drawn in black lines thus suffer a relatively greater increase of their conductivity than all the others under these circumstances.

This means an increased importance, as conductor, of the higher center at the expense of the lower nerve centers. We draw this conclusion because, without it, we can give no explanation whatsoever of the learning process. But this conclusion is not self-evident. Let us fully realize it.

Many are the assumptions which have to be made if we want to demonstrate with mathematical certainty that the higher center will finally have a lower resistance than either of the low centers. For example, it seems necessary to assume that the neurons of higher centers are more changeable under the influence of a flux of given strength than the neurons of lower centers. (This recalls the two assumptions of other differences between lower and higher centers made in the preceding chapter.) It counteracts the comparative weakness of the "higher" currents, and the comparative strength of the "lower" currents, at the start. For this assumption certain neurological facts could be referred to as favoring it. But for other necessary assumptions, one way or another, of an anatomical nature, our present knowledge is quite insufficient as a guide. Our diagram is of course a mere sketch. We therefore conclude quite dogmatically, but with the intention of arousing interest in the research problems implied, that virtually no current will finally go over the lower center. All will go over the black lines of the diagram. And always, in case of any stimulation, the two motor points will receive equal amounts of the nervous flux.

Thus far we can already speak of a habit established, a habit of concertedness of certain actions. It would be a habit of the class of sensory condensation. But it would not be a habit of the class of replacement of one motor function by another.

But now assume that the stimulation of one of the two sensory points is always stronger than that of the other reflex. Assume the stimulation of S_b—it makes no difference here which point we choose—to be the stronger one. Then the path $M^1/_b$ M_b would suffer a greater increase of conductivity than the path $M^1/_a$ M_a. Let this change be repeated, be continued, long enough. Finally the path lead-

ing from the higher center to the motor point M_a would be of no account as a conductor. All the flux coming down from the higher center would go to M_b.

Now combine these two changes: (1) All the current from either sensory point goes to the higher center. (2) All the current from the higher center goes to M_b.

The passing of the current from S_a to M_b then is what we mean by the functioning of the established habit. And the three essential conditions of its acquisition, let us not forget, were these:

I. Neurons must be capable of undergoing a lasting change in their conductivity in consequence of a nervous current passing thru them.

II. The period of time, within which both reflexes must function, is limited. (The greater the time interval between the two reflex functions, the weaker the resulting habit.)

III. One of the reflex currents must be stronger than the other.

The last two of these three conditions are purely circumstantial. But the first is a property of the nervous tissue essential to its service in the Other-One's body. Therefore we shall give it special consideration a little further on. Let us see first how the last two conditions are realized in the sample cases.

The teacher makes a statement, and the pupil pronounces it. This we regard as a reflex, altho it is a habit. The teacher asks a question, and the pupil responds "I don't know." This we regard as another reflex, altho it is a habit. Usually, however, the latter reflex or habit comes first. Usually the question precedes the statement. But not necessarily.

For example, the teacher enters the class and says—first stimulation—"Three times three?" with the rising inflection characteristic of every question. A little later the teacher

says—second stimulation—"Nine!" with the emphasis characteristic of every statement. We know perfectly that if he says "Three times three?" today and "Nine!" tomorrow, this will be without consequence. But if he says "Three times three?" a few seconds before—or (less usual) after—saying "Nine!" it is likely to have the consequence of forming the habit "Three times three is nine" or "Nine equals three times three."

However, he must say "Nine" more emphatically. He pronounces it with the falling inflection. If he pronounces it merely like a casual remark, like something relatively unimportant, like a mere question, like "Has anybody a pin?", instead of like a statement, no desired consequence is likely to happen. One current—and this one—must be stronger than the other. If they were equally strong, the pupil would develop to be as ready to say "I don't know" as to say "Nine," and thus might say neither. And that result does not satisfy a teacher, altho it satisfies some pupils, who refer to it, in the school jargon, by the ridiculous phrase: "I know it, but I can't express it."

Let us turn to analysing in the same manner the example of the candiless girl. The touch followed by the stretching movement is one reflex. The taste followed by the bending movement is the other. Sweet taste stimuli were by no means rare in that girl's life, but they (that is, those which were powerful) were intentionally, for a long time, kept from occurring in temporal nearness with a "candy touch" stimulus (and of course any other non-taste "candy" stimuli, sight stimuli especially, which for simplicity's sake we leave out of the discussion). Therefore no consequence resulted, and the reflex of responding to the touch by shaking off this sort of thing was retained.

And secondly, if the taste had not been so powerful, no consequence would have occurred either. It is a fact that

in the girl's life weak sweet taste stimuli sometimes occurred together with touch stimuli of the kind in question. Since they were weak, no consequence resulted.

As soon as the two conditions were fulfilled, and a powerful taste was permitted to accompany the touch, the candy eating habit began to establish itself.

Now let us turn to the example of the horse. The whip cracks, and the ear moves. That is one reflex. The skin in a certain spot is compressed, and the legs stretch. That is the other reflex. If the skin stimulus had been the weaker one, the habit of starting on hearing the whip would not have been established. Neither would the habit have been established if between the cracking sound and the compression on the skin there had always been a time interval of a minute or more.

It may be said that the same habit could have been—can at any time be—established by applying the sound to the ear and the pressure to the skin at the same moment. We shall say a little more about simultaneity of stimulation in connection with the next example.

Burnt child dreads the fire—proverbially. Sight of a flame followed by stretching of the arm is one reflex. Burning followed by bending is the other reflex. That the burning stimulus is the more powerful of the two, nobody will question. Sight most probably continues to act as a stimulus while the burning produces the bending movement. The stronger of the two simultaneous nervous currents then deflects the weaker one. In the last figure let us regard the black and double lines as indicating the stronger current. The weaker current would go in the main to the motor point nearest the end of the fine line. But if most or even all of this current is deflected by the simultaneous strong current, very little or no current flows in this direction, from S_a to M_a, while the two stimuli are simul-

taneous. It is in this case even easier than in the case of purely successive stimulation to understand why the long path (from S_a to M_b) from the sensory point of one reflex arch to the motor point of the other reflex arch should finally have a lesser resistance than either of the short sensory-motor paths. Thus the habit is formed. The Other-One learns. Of course, habit formation and process of learning are synonyms.

We must return now to the discussion of the fact that neurons in general have a capacity of suffering a lasting increase of conductivity in consequence of a nervous flux occurring in them. When in life we have in mind that a thing is capable of being changed by another thing, we often refer to the fact by saying that the thing is susceptible to the other. If, for example, a person's intestinal canal is materially changed by the introduction of cholera germs into the stomach, we say that the person's intestinal canal is susceptible of alteration by cholera germs, or that the person is susceptible to the cholera disease.

We may use the same term "susceptibility" with reference to the fact that a neuron slowly adapts itself to carry a nervous flux better in consequence of having carried it. The adaptation, being a biologic-chemical adaptation, can for that very reason be expected to be a lasting one. We know, or at least, we do not doubt, that immunity to a disease is a chemical adaptation and that it lasts. But while learning has a "lasting" effect in comparison with preoccupation, which rarely lasts to the next day or even hour, yet the effect is not lasting in an absolute sense.

The contact improvement of the synapses (preoccupation), which normally does not last beyond some minutes, differs from the adaptation of the neurons due to their susceptibility also in this respect, that it establishes itself quickly, whereas a true habit establishes itself more slowly.

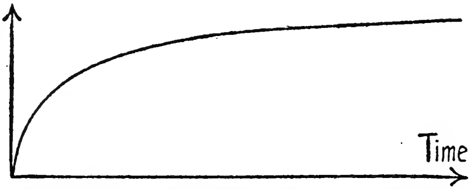
An initial spurt in learning something is as likely to be the effect of a mere "warming up," of preoccupation establishing itself and reducing the possibility of undesirable deflecting currents as of a peculiarly quick rise of the true learning curve. But the discussion of such details carries us beyond the scope of this book.

Nevertheless a brief answer should here be given in reply to the question: "What is the form of the true learning curve?"

One must expect that the magnitude of this change of conductivity due to the susceptibility of neurons depends on two factors, the intensity and the duration of the nervous current. The intensity is difficult to control. To make the stimuli very strong, is usually not practicable. The use of preoccupation for strengthening the current is in general unreliable because it depends on an individual factor. To strengthen the essential nervous current by providing other and inessential ones, weak enough to be deflected and captured, and at the same time to keep the latter from growing and deflecting the former, is often difficult. Therefore one depends in school and out of school chiefly on the duration of the currents acting on the susceptibility. And duration obviously means here simply repetition, since in the single intercourse of two reflexes the duration can rarely be prolonged.

Learning curves therefore represent time (or the number of repetitions) in the horizontal co-ordinate and the changing efficiency of the motor function in the vertical co-ordinate. Our figure shows us a typical learning curve, rising first quickly, later more slowly. A necessary inference from this behavior of the curve is that in a continuous process of learning, lasting, say, half an hour, the first few minutes are the most valuable part of the exercise. During the following minutes less and less is gained in

efficiency, and the last few minutes of the half hour add so little to the result that we might just as well have stopped earlier.



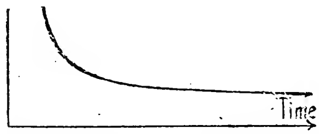
LEARNING DEPENDENT ON TIME.

This fact is established beyond doubt by experiment and agrees also with the ordinary experience of any one who has to practice anything, for example, the school-boy memorizing a foreign vocabulary. To read over the whole task five minutes a day for a sufficient number of days to complete it, is far more economical with regard to the total time required, than to complete the task in one continuous memorizing. If we continue the process only for five minutes, we do not make use of the uneconomical time part of the curve, toward the right.

We know that the opposite of learning, forgetting, is of as much consequence in actual life as learning. If we call forgetting the opposite of learning, we should do so exclusively in one sense, only with reference to "negative susceptibility." (The next paragraph will explain this term.) In other senses "forgetting" would be a mere synonym of "inattention" in the three social meanings of this word which we enumerated in the preceding chapter. A night watchman may "forget" to lock the door because he was sleepy. We may on leaving the house "forget" to lock the door because of preoccupation, or in consequence of another stimulus causing deflection from its path of the "locking" current at the critical moment.

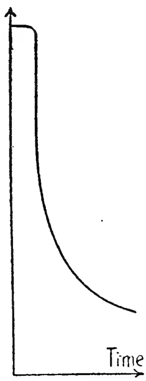
We have just used the term "negative susceptibility" as meaning that the "reduced" resistance of any nervous con-

ductor "very slowly rises again to its original measure." Since "negative susceptibility" is thus the capacity of a neuron for an adaptation to lack of function, its capacity for an adaptation to function may, by contrast, be called "positive susceptibility" as well as simply susceptibility.



FORGETTING DEPENDENT ON TIME.

The forgetting curve as shown in our first "forgetting" figure falls first quickly, later more slowly. This behavior refers only to the effect of the negative susceptibility. During the first few seconds or minutes directly following



FORGETTING DELAYED BY PREOCCUPATION.

a period of practice, there seems to be virtually no forgetting, and one might therefore be inclined to draw the forgetting curve as it is drawn in the second diagram going under this name, remaining almost on a level for a short time before it quickly falls.

This, however, is probably not a true forgetting curve. The lack of "forgetting" during the initial period is probably due to the preoccupation, that is, to still continued contact improvement in the synapses. The preoccupation disappears rather suddenly, and the curve then falls. The ordinate values of this curve thus represent, not one variable, but the sum of two variables.

We have had to speak in this chapter of a new property, not mentioned in the previous chapters, of conductive tissue, namely, its positive and negative susceptibility. This seems to be a proper occasion for making some further statements about the very differentiation of conductive tissue. An increase of conductivity of some neurons over the conductivity possessed by others is in a certain sense a continuation of differentiation. The differentiation, however, procedes along still another line. It leads to a distinction of neurons having a specially high "conductivity for a particular quality of flux" from all other neurons, which then have for this quality of flux only a more moderate conductivity. Innumerable facts of ordinary life, not to speak of experiments made in the laboratory, tell us that there is "specific" in addition to "general" conductivity. Whenever the term "resistance" is more suitable for the discussion than "conductivity," "specific resistance" (low) and "general resistance" (high) are to be distinguished. This is not a hypothesis, but a terminology needed for the description of the most ordinary facts of the Other-One's behavior.

We stimulate a definite area, say, the fovea, of the Other-One's retina with a properly placed piece of red paper. He responds by saying "red." We substitute a green paper. The Other-One responds by saying "green." Different muscles have acted. How could different muscles act when the same sensitive cells were stimulated? Now, unquestionably

the chemical changes in those same sensitive cells—the excitations—were different in the two cases. Nobody doubts that. It follows logically, that each excitation found the least resistance in the direction toward a particular motor point simply because it was of this specific chemical nature, and not of another one.

How is it possible for a single conductor to have several specific resistances, different for different qualities of flux? We can understand this without great difficulty. A nervous current, as we have previously said, is probably a wandering of ions. In a highly complex chemical substance like that which makes up nervous tissue, many kinds (hundreds or even thousands) of molecules may serve as ions. This is something like the streaming in filtering and in osmosis, but even more complicated than such processes.

The assumption of specific resistances is a brief expression of the fact that the motor outlet of a nervous current is often determined by the quality of the flux and not merely by the anatomical condition of the flux taking its origin in a particular sensory point.

(For the reader who is not an ordinary student it may be said here that the author of this book has shown elsewhere—The Fundamental Laws of Human Behavior, pp. 158-167,—that the distinction of a general resistance and specific resistances in neurons permits a mathematical demonstration of the "possibility" of the responding motor point being definitely changed by reversing the "temporal order" of qualitatively differing stimuli. For example, the Other-One responds in one way to hearing "tack" pronounced, in another way to hearing "cat.")

Naming colors red and green is a habit, as is all definite speech. Clearly, a neuron may take a specific resistance, a specific conductivity, during and in consequence of the process of learning, thereby revealing its susceptibility. But

it is also clear that the specific resistance of many a neuron is the result of heredity. We know that in animals the reflex response to red, for example, differs from the reflex response to green, under certain (not by any means all) experimental conditions. Remember a bull or a turkey gobbler. Remember also the distinctive coloring, the distinctive sounds, the distinctive odors of many species, which almost unquestionably serve definite reflexes.

It is worth while to mention in this connection that the differentiation of neurons into many classes having distinct specific conductivities (in addition to general conductivity) is a great aid to the architect of the nervous system. This differentiation enables the architect to get along with a smaller number of building elements, a smaller total number of neurons. A common path from the sensory point in question can serve more reflexes than one until a point is reached, close enough to the several motor points, where division is necessary in order to call forth this or that of several reflex actions serving that sensory point. Even tho the total number of neurons is great, five thousand millions or more, there must be economy in their architectural employment, considering the actual complexity of the Other-One's life.

Specific conductivities not only help us to understand why the Other-One reacts differently to different stimuli applied to the same sensory point. Specific conductivities also help us to understand why the Other-One calls "different" stimuli sometimes "similar." For example, the artists call green and blue similar, give them a common name and call them cool colors. A common name, where it does not indicate equality, always has the significance of "similarity." But the usage of language, it is well to remember, inconsistently does not always provide a common name for things which are called similar,—thus causing not infre-

quent trouble to the psychologist. Tones of piano keys which are neighbors, are called similar by the psychologists, altho they have no common name. And tones which the musicians call Octaves, Fifths, Fourths, and which are apart, maybe very far apart, on the key-board, are nevertheless called similar by the psychologists,—and again the usage of language has not provided a common name.

In some of these cases, obviously, each nervous current consists of two (or more) kinds of ions. One kind finds its specific (that is, lowest) resistance over the neurons in the direction of one motor outlet, another kind in another direction. So the flower picked up by the Other-One may be called by him blue, or it may be called dark. Whether one or the other competing motor outlet "beats," depends on many circumstances in the functioning of the system, such as "preoccupation," or perhaps the existence of another current going already independently (and therefore deflecting) toward that particular motor outlet. The piece of coal picked up by the Other-One is never called blue by him (tho perhaps "uncolored") ; but it is often, like the flower, called dark. There must be an ion class in both currents ("coal" and "flower") which easily finds its way toward the "dark" motor outlet. It must find specific conductivity of the proper kind in the neurons there.

In other cases the nervous currents may differ by the frequency with which ions break loose from a larger molecule. If the frequency differs little, the same neuron invites, so to speak, both currents by offering them a specific conductivity. Thus the tones E and F, or F and F-sharp, are similar.

In still other cases ions may have such geometrical designs in the grouping of their atoms that they find a particular neuron with specific conductivity favoring both. A neuron accommodating, so to speak, a group of 30, may also

readily accommodate a group of 45 atoms,—perhaps on account of the same factor (15) existing in both numbers. But the same neuron, favoring 30, may not quite so readily favor an ion grouped together out of 31 or 32 atoms.

The reader familiar with acoustics probably notices already that the numbers 30 and 45 refer to a case of the tones, say, F and C; and that the other numbers refer to a case like F and F-sharp. The most distinguished author on the psychology of tone, Stumpf, has used the term "specific synergies" with reference to the interrelation of neuron functions of this kind, as exemplified by the numbers 30 and 45.

One neuron, then, may readily accommodate both the 30 group and the 45 group of atoms, but not readily both the 30 group and the 32 group. Another neuron, however, may accommodate most readily the near frequencies of tone stimulation, but not readily both the 30 group and the 45 group.

Thus one can understand why F and C, in a certain sense, deserve to be regarded as more similar than F and F-sharp; in another sense F and F-sharp more similar than F and C.

These examples of what "similarity" means in the Other-One's life, are given here purely as suggestions indicating where the true problem lies. Why are there such identities of muscular reaction,—replaced commonly by the brief name "similar"? These problems are unquestionably of a chemical nature. The chemistry of the neuron, some time in the future—not too remote, let us hope—will unquestionably give a simple solution to problems which long have bewildered and still perplex the student of the life of the Other-One.

There is, concerning the fixation of a new path, a very important problem still left. We have reason to believe that in addition to the fixation by susceptibility, which makes a

long path function as if it were a short one, there is another kind of fixation. There seems to be a secondary fixation which actually shortens the nervous path, but only in case the repetitions making up the learning process are extended over weeks and months. We can explain this shortening by the aid of a comparatively simple hypothesis.

All tissue growth is known to be either by cell division or by a change in size or shape or other respects of already existing individual cells. Different kinds of tissues, however, show a remarkable difference with respect to these two kinds of growth at the different ages of an animal. In certain tissues, cell division can occur all thru life. The necessity of this in certain tissues is clear, for example, in those tissues of which our skin consists. When we have received a considerable wound, involving the loss of some skin, the cells at the edges of the wound divide. The resulting new cells increase in size and divide again; and so on until the opening is completely covered with new skin. Without cell division any new skin could hardly be formed, since there is a limit to the size which individual cells may normally attain. But scarcely any animal goes through life without frequently receiving wounds.

In other tissues cell division becomes impossible after the animal has reached a certain age. Since the muscles are of special significance for animal behavior, let us take the muscles as an example. It seems that in human muscles cell division becomes impossible after the age of from twenty to twenty-five years. From this follows the important fact that, in order to become an athlete, a person must exercise his muscles and thus induce both cell division and cell growth before the age of twenty-five years at the latest. If he has failed to do this, the number of muscle cells which he possesses is so small that exercise, because of the limited growth of the individual cells, will now only

slightly increase the bulk and therefore the total strength of his muscles. This age limit for cell division differs in tissues of various kinds.

The bulk of the nervous system consists of nervous tissue proper, that is, the conducting tissue, and of supporting tissue. In the latter, cell division may occur at any age. In the nervous tissue proper, however, cell division, that is the multiplication of neurons, stops before man begins his postnatal life. It has been found that about three months before birth man has as many neurons as he will ever have in his life.

At this time the vast majority of these neurons are in the undeveloped condition which we have already described. They are little balls without any branches and therefore of no value for the conduction of an excitation. They develop into complete conductors at various stages of the Other-One's life. Some develop early, in order to serve those muscular activities which the baby needs immediately on entering into life, for example, the activities of sucking and swallowing. Others develop during the succeeding years of childhood and youth.

It is a peculiar fact, however, that even in old age there are still many undeveloped neurons present in the Other-One's brain. The conclusion offers itself that these undeveloped neurons enable him to acquire, even at an advanced age, certain new responses to stimulations.

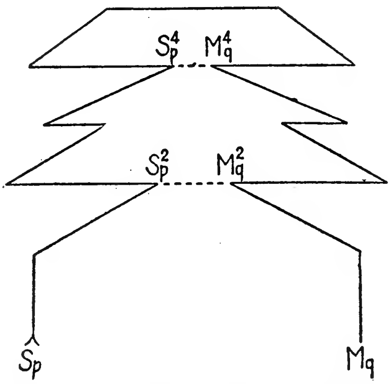
The numerical possibility for the architect of leaving, to the time of death, a considerable number of neurons undeveloped and unused, appears from the fact that the total number of neurons in the brain is enormous, uncountable. A day of twenty-four hours contains 86,400 seconds, a hundred years but little more than three thousand million seconds. How could we count the neurons in the brain

even if they were only an equal number of millions,—and they probably are more!

Thus it does not matter much if the Other-One takes a few millions of undeveloped neurons with him into the grave, provided that thereby he is at any time of his life capable of forming new useful habits. Capable also of regaining nervous functions which he has lost in consequence of a lesion within his brain,—say, a bullet having passed thru his brain. In such a case, if he is lucky enough to remain alive, he is at first—and he may be permanently—found incapable of performing certain skilful movements and of reacting in any way to certain stimulations.

If a piece of his brain is destroyed, it does not regenerate like a piece of his skin. What takes the vacant place is not the same kind of thing. The conductive tissue does not regenerate. Its room is filled out with supporting tissue. The neurons lost, are lost forever. The functions lost, however, may be entirely or partly regained, just as if they were new habits.

We stated that a new nervous path, after having been fixed in its original length thru the susceptibility of the neurons of which it consists, may later be shortened. We can now explain how this shortening can come about. Suppose a new path leads now, instead of to the point M_p which in our figure may be imagined to correspond to S_p, by way of higher centers to a non-corresponding point, say, M_q. S_p and M_q are supposed to belong to two reflex arches which are very remotely related, so that the first resulting path goes over very high centers and is of a very roundabout and zigzag nature. The figure represents this diagrammatically, without suggesting that the path in the brain would actually present itself to the eye as a symmetrical figure like this.



SHORT-CIRCUITING IN THE NERVOUS SYSTEM.

What is important in the diagram is only that in various places, for example, at $S^4{}_p$ two points of the path are by chance very near each other. Let us assume that in such a case we have between the two points a peculiar, growth inducing, biological condition, just as we should have, if the path were a metallic conductor carrying a high potential current, an electrical tension likely to break thru the insulating substance in sparks. This simple hypothesis is sufficient to explain the second kind of fixation of the variation of a nervous path. The biological tension, so to speak, between $S^4{}_p$ and $M^4{}_q$ causes one or more of the undeveloped nerve cells to grow and send out branches in either direction of the tension.

The consequence of this development of a new connecting neuron is a shortening of the path leading from S_p to M_q by practically putting out of function the part above $S^4{}_p$ $M^4{}_q$, owing to the higher resistance of this upper loop. The result of the new growth is that the response at M_q to stimulation of S_p occurs with greater quickness and also with greater definiteness, exclusiveness, for less of the flux from S_p can now reach motor points other than M_q.

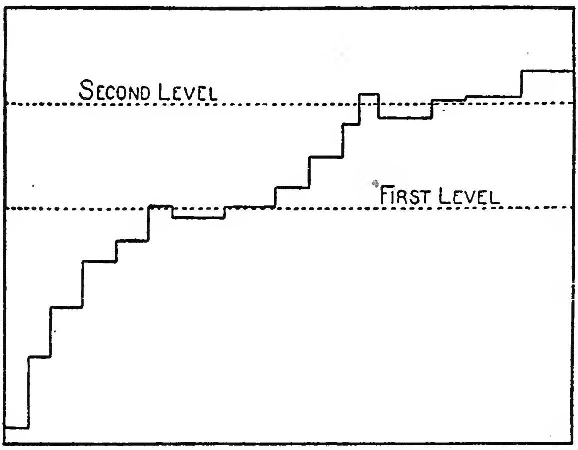
The same kind of shortening of the path may occur later between $S^2{}_p$ and $M^2{}_q$. Here again the biological tension

may cause the development of a new connecting neuron out of an undeveloped nerve cell. The length of the total path leading from S_p to M_q may thus be reduced to almost that of a reflex arch. The response at M_q to a stimulus at S_p must then occur with the same quickness and definiteness as a reflex. That habits can become very much like reflexes is well known. In the drilling of a soldier good examples can be found by any observer.

Action of this kind is called automatic. It scarcely differs from reflex action in any respect, save in its origin, which is not hereditary. Its resemblance to reflex action is illustrated also by the slowness with which the destructive influences of certain diseases of the brain attack it. When a nervous disease has made a man's actions entirely illogical, certain automatic actions still occur with the same promptness as most reflexes, for example, oaths—in people who have acquired the habit of swearing in early life. This indicates the probability that our hypothesis agrees with what actually occurs in the brain. Since the disease attacks the higher centers of the brain before the lower centers, the development of the automatic action of swearing seems to have consisted in the functional cutting out of the higher centers from the path, as explained in the diagram of our figure.

If the distance between $S^2{}_p$ and $M^2{}_q$ had been less than the distance between $S^4{}_p$ and $M^4{}_q$, the shortening of the path might immediately have occurred here. The possibility agrees with the observation that habitual reactions are sometimes made automatic, quick and sure, only in numerous stages, sometimes become completely automatic almost at one time, without any explanation of this difference offering itself in the circumstances of the experiment.

Another interesting fact which may have its explanation in this short-circuiting is illustrated by our figure of tests during the learning process. Each of the small steps of the figure indicates one test. Because of the many factors which disturb every test we do not expect that every step rises with regularity above the preceding test. But we hardly expect to find a tendency for the values to remain virtually on a level during several successive tests, only to rise again quite rapidly afterwards. Nevertheless this is what sometimes has been found.



TESTS DURING THE LEARNING PROCESS.

It is possible that each of these apparent levels is really, not a plateau, but a gradient of a small angle, and indicates a period of slow progress of learning,—the ordinary slow improvement in skill, speed, or whatever may be tested. But while the final adjustments of cutting off a loop in the nervous system are being made, the tests of the person's efficiency must reveal a more precipitous improvement. After this the efficiency rises again slowly, until another neuron, having had time enough to grow, extends its fiber in the line of biological tension, cuts off another loop and thus raises the efficiency again more quickly during the

following tests during which the synapse establishes itself completely. Instead of speaking of levels, we ought, if the explanation by this hypothesis is correct, to speak rather of alternating periods of comparatively slow and of quickened progress.

We have said much in this chapter about the fact that the Other-One learns. We have meant by it that he gradually varies those responses with which Nature has endowed him thru heredity giving him reflexes. We have discussed the conditions under which learning takes place. Some of these conditions are circumstantial. They refer to the nature and manner of stimulation. Other conditions are intrinsic. They refer to the biological properties of the conductive tissue.

If the Other-One did not learn, he would not differ much from plants. He would still be more mobile than plants generally are. His nervous system, built up out of reflex arches, would be an essential factor in securing for him this mobility. And his nervous system would therefore still be a distinguishing mark. Nevertheless his life would not be very different from plant life. (Do we not say that some of his functions, e. g., digestion, are "vegetative"?) But he varies his actions during his individual life. He varies them enormously. And thus plants become quite incomparable to him. He varies: he learns or wills.

Learning, as thus far considered, is a process which in each case goes on rather slowly.—The Other-One varied from what we were accustomed to see him do. He varied from his reflex actions. We became accustomed to his habits, and he varied from his habits again. Still in every case the variation of response established itself so slowly that we could speak of a more or less conspicuous "process" of learning.

However, in many of the higher animals as well as in the Other-One of our own species we observe a kind of variation of response which surprises us thru the lack of any slow process of formation of what, nevertheless, looks like a new habit. We are surprised by the quickness with which the change came about. For example, a dog which viciously attacks every stranger and accepts no offers of friendship from them, is one morning found dead, poisoned. At the same time there are signs noticed of unwelcome visitors to the house. Obviously these succeeded in "teaching" him in a few seconds to behave quite differently toward strangers and silently to accept food from them. In the Other-One's life we call the counterpart of such quick teaching, not "learning" or "habit formation," but "willing". And this teaching process we often call temptation, no matter whether the teacher is a person or a material situation.

The word "will" plays in literature two especially important roles. First, in the phrase "freedom of the will;" second, in the phrase "strength of the will."

We read in mythology that Heracles once met on a division of the road two women who called his attention to the advantages of the one and the other continuation of the road. They tried to teach him. One did not succeed in teaching him. The other did succeed. He learned.

But where the process of learning is so brief, we don't call it learning. We call it willing. And since in a case of learning where the time is so short, where repetition is so inconspicuous, the outcome is so difficult to foretell by the onlooker, we call the outcome an accident. It seems like the weather, like the wind which blows whence and whither it wishes. In this sense we speak of "freedom." Freedom of action in the animal world signifies the same that is meant by accidents in the world of physics.

Why do we speak so little of accidents in physics and so much of freedom in human life? This is itself an accident. Because the accidents happen to be the very facts which a professor of physics is least interested in, he mentions them rarely in his books and lectures. But the professors of the various forms of conduct in human society and of human history happen to take more interest in the cases of quick and unsure learning (in freedom) than in the slowly and surely progressing cases of learning (in habit). Therefore we hear so much talk of freedom of action and read so much about it in literature,—in fiction as well as in the literature of law and religion.

The Other-One's conduct is free, uncaused, only in the same sense in which the issue of a disease, the outcome of a war, the weather, the crops, are free and uncaused; that is, in the sense of general human ignorance of the causes of the outcome.

Paralysis of activity is often said to be the consequence of too much talk of universal causation. But surely the energetic and ambitious man is not paralyzed thereby. He is the tool used by nature to shape the destinies of the world. How could the admission by others of his importance in the causal connections of events paralyze his activity? The idle and indolent person may excuse his lack of activity by saying that it is his nature to love inactivity, that he cannot help it. But who would have any more respect for him on that account? Of course it is not his having heard of universal causation that makes him indolent.

The lesson from history is very significant in this respect. But it must not be read one-sidedly. It is all right to point out that the fatalistic Islam is losing piece after piece of its dominion. But the same fatalistic Islam also conquered a world and for centuries kept all Europe both

in terror and in admiration of its cultural achievements. Thus it cannot be its fatalism that determined its rise and its downfall.

Next to "freedom" of will, "strength" of will is probably the most disputed phrase containing reference to this quick and unsure process of learning. We think of Napoleon as a man of a strong will. We think of Micawber as having a weak will. Napoleon often "learns quickly," makes quick decisions. Micawber also often finds himself in situations where a man "learns quickly," makes quick decisions.

But in Micawber's life it is impossible to put these decisions under one of a few chapter headings in his biography, under one of the "aims" of his life. Some of these decisions would have to go under eating, others under drinking, some under sleeping, others under looking out of a window, some under promenading, others under gossiping,—and whatever happens frequently in everybody's routine of daily life. It is impossible to write his biography with a table of contents made up of a list of his "aims" or "purposes." In Napoleon's biography such a table of contents could be made without difficulty. Such is the difference to which we refer by weakness or strength of the Other-One's "will."

Freedom of will and strength of will are clearly terms which are of far more significance to the sciences of social institutions than to the science of the Other-One's individual activity. They are sociological rather than psychological terms.

Of peculiar significance in the variation of the nervous path, and thus in the variation of the response to a definite stimulation, is the muscular or so-called kinesthetic sense. In a previous chapter the fact has already been referred to, that the muscles are not only motor organs but also sense

organs. Many kinds of concerted action depend on the intactness of the sensory nerves serving the muscles concerned. A workman received a knife wound in the spinal cord. Complete recovery occurred, with the exception that the

WILLING IS A SENSORY-MOTOR FUNCTION.

right hand and lower arm remained perfectly anesthetic. The muscles of the hand and arm functioned almost normally. But movements, even very moderately complicated, could no longer be performed unless the man saw his hand and its movement. The illustration shows his behavior when requested to form a ring with his thumb and index finger. He could do this fairly well when permitted to look at his hand. Otherwise it was impossible, in spite of the muscular capacity to perform this action.

Of course, that man did not have either a reflex or a habit (no one has) of making a ring with his finger and thumb. A normal person, however, can be taught to do it, either by the slow and sure process of training him or, just as well, by the quick and unsure process of persuading him. A normal person can "learn" or "will" to make such a ring. This workman, too, can learn or will to do it, but only under condition of using his eyes. In this respect he differs from normal persons. The example shows clearly that "willing" is a sensory-motor function and nothing else. Of a mysterious "will power" in the Other-One the psychologist of the Other-One has no knowledge, because

the sense organs do not reveal it to him. Any interference with the Other-One's nervous currents changes the reaction of the motor organs in accordance with the nature of the interference. If there is no such interference, there is no change in the reaction.

If the psychologist is asked to tell what the difference is in terms of nervous functioning between willed and unwilled actions of the Other-One, he can say little more and will say no less than that so-called willed actions are those of a more complicated, unwilled actions those of a less complicated nervous functioning. The border line between the two classes is then fluctuating, is a matter of expediency, of taste. And with this statement is in perfect agreement the lack of a uniform usage of the terms "willing" and "unwilling" among lawyers, theologians, students of the social sciences, writers of fiction, and so forth.

CHAPTER VII

How the Other-One's Developed Nervous Functions Show Up Anatomically.

Interest in the behavior of the Other-One is, after all, not of so recent origin as some may think. The Greek classics and Greek archeology show us that the ancients were--and in what manner they were—interested in his behavior. They thought that he had within him a ruler under whose command were constantly the parts of his body. This ruler was a gas-like, shadowy, substance which they called his soul,—psyche. It entered his body at birth, at the first cry, and left his body at death. Death they pictured as a shadowy being, sometimes in the shape of a person, sometimes in the shape of a butterfly or bird, leaving his mouth.

While this shadow, his soul, was within the body, it was supposed to take a special part of the Other-One's body for its residence. What part this was, there was much speculation about. Naturally they concluded that an anatomical region which appeared to be very active in emotions, was most probably the seat of the soul. Since we often breathe heavily in a state of emotion, the chief breathing muscle, the diaphragm, was thought to be the seat of the soul.

The Greeks called the diaphragm "phren." It is not very strange that in the usage of language the seat of the soul became confused with the soul itself. In the language of the Greeks phren therefore came to mean soul. This is the reason why in the eighteenth century the phrenologists, who were trying to put—and with some success did put—"psychology" on a higher scientific level, gave it a

new name and called it "phrenology." Phrenology like psychology literally means science of the soul.

It goes without saying that those eighteenth century phrenologists (especially their master, Gall, a physician) had nothing in common in ideals or purposes with the charlatans who have been going under the same name during the nineteenth century,—and even to the present day.

Our ancestors from the northern parts of Europe thousands of years ago located the soul, not like the Greeks in the diaphragm, but in another muscle which is quite active during many emotions. So they developed the habit of speaking of different people as having a big, soft, hard, broken, warm, cold, etc. heart. And like the Greeks they did not mean thereby a muscle, but referred to the Other-One's soul.

During the last centuries, with the rise of the science of anatomy, even popular language has come to recognize that the Other-One's behavior depends on his nervous system more than on any other part of his body. Popular language, however, does not speak of the "nervous system," mentions but rarely the Other-One's nerves, and speaks usually of his "brain." Why is that so?

The brain is so much more conspicuous than any other part or parts of the nervous system that it is the only part for which there exists a truly popular name, the very name "brain." One can buy brains in the butcher shop. Other parts of the nervous system are not offered for sale there as such, because they cannot easily be removed from the carcass and handled separately.

The question which readily suggests itself and which this chapter will attempt to answer, is: Why have the highly developed nervous functions, with which we have become acquainted in the previous chapters, led to making a part of the nervous system so conspicuous over all others? The

functions with which we have become acquainted are reflexes, instinctive actions, and habits.

The fewer instinctive actions and habits a species of animals can show, the lower it is placed in the stage of evolution. The more instinctive actions an animal has, and especially the more habits instead of mere reflexes, the higher we call it. In general higher animals—everybody knows—also have a larger, lower animals a smaller brain.

Reflexes, instinctive actions, and habits depend—we have learned—on definite structural, architectural, peculiarities of the nervous system. It seems interesting and promising, therefore, to raise the question why these structural peculiarities should result in the remarkable anatomical conspicuousness of one bulky mass of nervous tissue, that is, in a "brain" making its appearance,—and a brain ever increasing in size. Why does not, in the process of evolution from lower to higher animals, merely the total quantity of scattered conductive tissue increase, but remain scattered thruout the body?

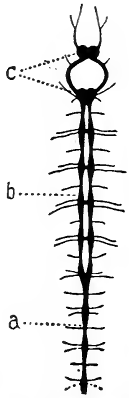
Local responses, we have seen, require nothing further than reflex paths, which, being entirely independent of each other, may be located anywhere in the body provided the ends of each path are in the proper sensory and motor points. Paths serving simple reflexes may be scattered and need not become conspicuous save to the investigator armed with a microscope.

But the necessity of a number of muscular actions occurring in concert introduces at once a new element into the anatomical aspect of the case. An animal as low as a worm already shows this new feature clearly. In our figure of the bulk of the nervous system of an earthworm, showing its anatomical form in the head, the middle segments, and the tail, we see lengthwise a series of black nodes. Each of these nodes serves one of the segments of which the

worm consists. We know these segments well from mere observation of this familiar animal with the naked eye. For the locomotion of the worm it is essential that each of the segments be capable of contracting separately from all the others.

Since the worm's body is long and narrow, we expect that successive pieces, from the front to the rear, should function in relative independence. To make this still clearer, let us remember how the worm moves forward. The abdominal side of the body possesses tiny bristles pointing backwards, so that no part of the body easily slides backwards on the ground. If, then, a fraction of the body, at the front end, lengthens in the manner which everybody knows from observation, the front end must be pushed forward.

Suppose now the first half of this front end, the head, so to speak, remains inactive on the ground, but the second half actively shortens, and during the same time an equally

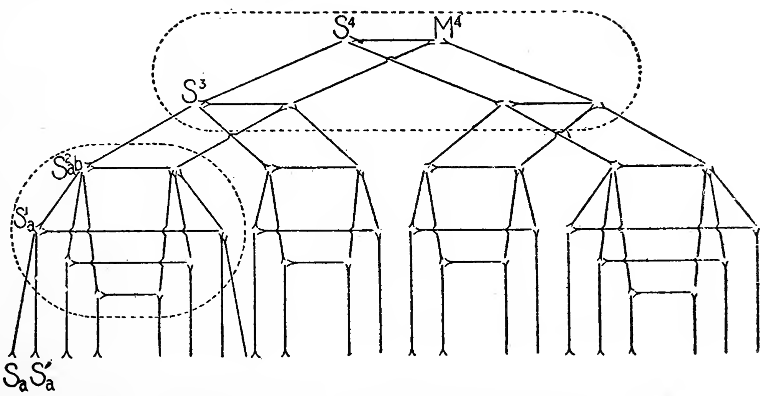


THE NERVOUS SYSTEM IN THE HEAD, MIDDLE SEGMENTS AND TAIL OF A WORM.

long third piece directly behind actively lengthens. The effect must be that the elements of the second piece are, more or less, pushed forward.

If now the third piece, which has just extended itself lengthwise, contracts lengthwise, and the directly following fourth piece lengthens at the same time, while all the rest of the body remains inactive on the ground, the elements of the third piece are pushed forward, more or less. When in the same way the fourth and every succeeding piece has been moved forward, we can say that the worm as a whole has made a step forward. It is immediately clear that the nervous system of this animal must be so constructed that the successive pieces can function in relative independence. They must be nervously furnished in such a manner that they can function like so many separate organs, that each as a whole possesses what we have called local responsiveness.

Each segment must have, in a sense, its own nervous system. Therefore there are visible to the eye as many "nervous systems" or "ganglions" as there are segments. The "swelling" (this is what "ganglion" literally means), the conspicuous node, results from the fact that the reflex arches of the segments (in each of which there are



GROUP FORMATION IN THE NERVOUS SYSTEM.

naturally many muscle fibers) must be anatomically pulled together in order to be given a common superposed arch or "center." And thus they form a relatively bulky and

conspicuous mass, the node, the ganglion. In our figure "group formation," which is of course a mere sketch illustrating principles, such a node may be thought to be the mass of nervous tissue included in the dotted ellipse within which the point S^2_{ab} is located.

Observation with the microscope reveals that each of these ganglions, even at "a" in the figure of the worm, consists of two relatively separate parts, we may say of a right ganglion and a left ganglion. Toward the head this doubleness becomes very conspicuous, and the nervous cord in the region marked "b" in the figure assumes a ladder-like appearance. In the head region, marked "c", the two halves of the cord separate so widely because they have to pass around the mouth opening, for the cord in the invertebrate animals is located on the ventral side of the animal; and the mouth opening is located on the same side since animals naturally feed from the ground. In front of the mouth the two halves of the cord join again and carry the two head ganglions (or the one double ganglion of the head, if we prefer to say so) of which we shall have to speak a little farther on under the name of the brain.

The fact that each segment of the worm has a right and a left ganglion, is easily understood. The right half and the left half of each segment sometimes function in relative independence. This is the case whenever in the region of this segment the worm is not straight, but curved,—when the path of the worm on or in the ground is curved in this place. In each half of the segment the muscle fibers have then their concertedness of action. Each half may contract without the other contracting too. But usually both halves act in concert, and for this purpose the "rung of the ladder" unites the two ganglions.

There is not an equally pronounced separation between the upper and the lower half of each segmental ganglion.

Why not?—Animals, generally speaking, live on the surface of the earth (only exceptionally above or below its surface) and move forward or to the right or the left on the surface. They do not, in general, move up into the air and down into the ground, notwithstanding exceptions, of which the very earthworm may be said to be one. Even the earthworm, in its wanderings, obviously turns much more frequently to the right and to the left than downwards or upwards. So the "local response" of the upper, or lower, half of the segment without the other half is not an action for which special provision is as important as for the local response of each of the lateral halves.

The front ganglion and the next, directly behind the mouth opening, are larger than any others. Using the customary designation "brain" for the most conspicuous mass of nervous tissue in the animal body, one could call these two ganglions together, at "c", or the frontal ganglion alone the worm's brain. But the very fact that one hesitates before deciding to call either both together or the frontal one alone the brain, demonstrates how misleading this very appellation really is. Apart from the greater size there is nothing distinguishing found in the worm's brain. The function is of the same kind as that of any other ganglion.

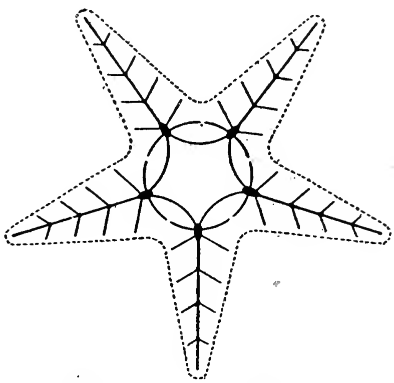
The muscle fibers are especially numerous in an animal's head. They act there in especially numerous combinations, in many varied forms of concert. Not only are movements of the head of great importance for locomotion—the rest of the body follows where the head goes—, but there are in the head also the mouth organs which move while taking in the food. And because of the importance of the muscle actions occurring in the head, it is only natural that there are placed there also very numerous sensory points, whose stimulation calls forth those varied muscular reactions.

The large size of the head ganglions is simply the result of the multiplicity of forms of concertedness among a multiplicity of reflex functions of the head segment,—with one exception.

This exception consists in the need of having a certain concertedness of all the segments of the body established in such a manner that this total concertedness—or integration—depends on stimuli received by the head rather than on stimuli received by any other part of the body. The head—that is, the part that moves in front of all the other parts—is more likely than any other part to receive any kind of stimuli for the reason that it moves toward these stimuli. And the head will also receive, in general, the most significant stimuli. To give a simple illustration, having gone into a cul-de-sac, it is the head, obviously, which will receive whatever stimuli may be characteristic of this peculiar situation, which demands that for the time being the tail assume the role of the head and take the lead in the locomotion.

Since the sense organs of the head are, then, the most important sense organs for this total concertedness of action, it is quite natural that by the superposed arches serving this total concertedness all the lower centers should be drawn together within the region of the head rather than in any other locality of the body. In our figure "group formation" these superposed arches, the highest centers, are represented in the dotted ellipse within which the points S^3, S^4 and M^4 are found. The addition of the nervous tissue of these highest centers of course helps to make the head ganglions relatively still more big and conspicuous. Nevertheless, there is no particular kind of functioning found in this "brain" which cannot be found in the other ganglions too.

A starfish presents to us some very interesting features. It may be compared with a collection of worms having one common mouth. As our figure shows, each arm of the starfish has a series of ganglions, strung on a cord, so to speak, comparable in virtually all respects with the series of ganglions of the worm. But when at the ganglion behind the mouth opening the cord splits, it can not as in the worm simply unite again in a ganglion before the mouth, but on the right it becomes identical with the corresponding left branch of its neighbor cord, and on the left it becomes identical with the corresponding right branch of its neighbor cord.



NERVOUS SYSTEM OF A STARFISH.

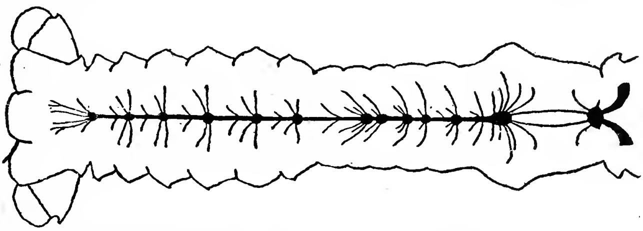
So the starfish is like five worms having a common mouth and of course no head, and—what interests us most—having a common "brain" consisting of five ganglions. This case shows perhaps even more strikingly that "brain" does not signify anything but the most bulky part of the nervous system. Instead of saying that the starfish has one brain consisting of five ganglions, we can just as well say that it has five brains whose co-operation is brought about by a cord running around from point to point of the pentagon at whose corners these brains are situated.

So much, however, has already become clear to us that the most bulky part of any animal's nervous system—call it brain or no—is very likely to be the location of the highest of all the nerve centers which an animal possesses. And inversely, the higher the nerve centers possessed by an animal, the greater seems to be then the probability that somewhere, and most likely in the head, a particularly bulky mass of nervous tissue will make itself conspicuous.

We need not prove that the so-called higher animals possess higher nerve centers than the lower animals, for the greater complication of their nervous system and the resulting greater complexity of their life activities is the very reason why certain animals are called higher in comparison with others, which then, of course, are called lower animals. Thus we can rewrite the last sentence of the preceding paragraph as follows: The higher animals are more likely than the lower animals to possess one bulk of nervous tissue which makes itself particularly conspicuous. Or, the higher an animal, the more conspicuous in the body is its brain likely to be. The following figures will illustrate this statement further.

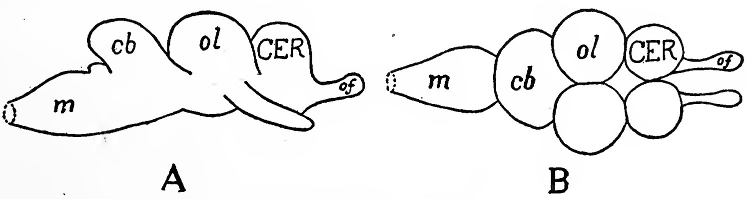
The crayfish is an animal considerably higher than the earthworm. Yet there is no essential difference in the conspicuous anatomical features of the two animals. We notice, however, that the ganglions before and directly behind the mouth opening are relatively bigger. This is to be expected, because the crayfish has numerous appendages. Each of these appendages consist of parts. Each of these parts may at times have to react in relative independence of the other parts, that is, in a local reaction. But all the parts often have to act concertedly, while yet the whole appendage, of which they are a part, acts locally, that is, independently of the other appendages. Very often two appendages, especially those located symmetrically at the

two sides of the body, act in concertedness. Very often a still greater number of appendages act in concert, especially when responding to stimulation occurring at the sense organs of the head, which are here much more elaborate than they are in the worm. So the large size of the head ganglion results directly from the need of systematized multiple conduction paths which place the muscles in varied ways at the disposal of the sense organs.



NERVOUS SYSTEM OF A CRAYFISH.

The vertebrates have, in their head, sensory and motor organs of still greater significance than those found in the head of the articulate and lower animals. The reflex arches of all of these, and also of the sensory and motor points of the remainder of the body, must be united into groups, and these groups, again, must enter into manifold combinations in order to serve the more varied needs of a more richly furnished organism. Accordingly we find in the head of a fish a particularly large accumulation of nerve centers. The fact that this "brain" results from the formation of groups of reflexes, and groups of these groups, and higher groups again, is very apparent to the eye. The brain appears clearly as an agglomeration of numerous gan-



BRAIN OF A FISH.

glions. In some of them the division into a right and a left ganglion is very striking. We have seen that this division is very natural because of the frequent necessity of local responsiveness on either side alone.

The reader has undoubtedly noticed that A in the figure shows a side view of the same ganglions which in B are seen from above.

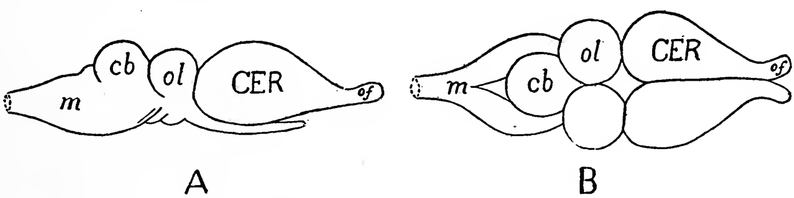
We have mentioned that the reflexes of the parts of the body other than the head must be well co-ordinated with those serving the head itself, so that the forward part of the body may be in more than a mere geometrical sense the leader of the body. However, there are certain reflexes which do not require a particularly close connection with those of the head. They are the reflexes which serve the so-called vegetative or visceral functions of the body. Let us make this clear by examples.

The approach to an article of food lying in the neighborhood is controlled mainly by the reflexes within the head; it is a response to sights, sounds, odors, tastes received by the sense organs of the head. But the approach could not take place without the co-operation of the reflexes on which the locomotor organs depend for their function; and these organs are to be found in the remainder of the body rather than in the head. So there must be here a close connection between reflexes within and reflexes without the head. On the other hand, there is scarcely any reason, why, for example, the intestinal activity of digesting food should be influenced, enhanced, or impaired during the time of this or any other specially directed locomotion of the body, or why this special locomotion should be influenced by the intestinal activity, save the extreme cases of an empty or an already overloaded stomach, to use familiar language. We are not surprised, then, to find in any animal the visceral nervous system (often called "auto-

nomic," that is, "self-governing") rather separated from the remainder, and to find in the nervous accumulation of the head which we call the brain "the center" not so much of the whole nervous system, but only of a part, altho by far the largest part, of the nervous system of an animal.

In comparing further vertebrates, higher than the fishes, our interest is confined to this part of the nervous system which is accumulated in the head. We notice that the different ganglions of the "brain," passing from lower to higher animals, do not grow in equal proportions. We must give these ganglions names in order to be able to refer to them severally. Our figures, each of which gives a side view, A, and a view from above, B, contain their ordinary anatomical names. There are five subdivisions from front to back, of which three, the frontal ones, are more obviously divided into a right and a left half than the other two. The ganglions of the brain are frequently also called lobes. Thus "ol" in the figure means "optical lobe," "of" stands for" olfactory lobe." Of the other abbreviations "m" means the "medulla," joining the cord, also called bulb because of its shape. The "cerebellum' or small brain is marked "cb, the "cerebrum" or large brain "CER."

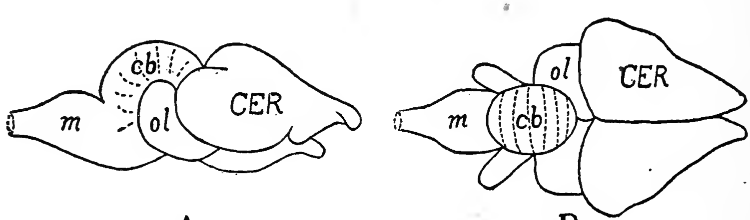
Compare with these ganglions of the fish those of the frog. Their relative size has changed in favor of one, the cerebrum. This is still more obvious in a still higher an-



BRAIN OF A FROG.

imal, a bird. The two halves of the cerebrum, the so-called hemispheres, are now, especially in the view B, from above, the most conspicuous part of the whole. The same de-

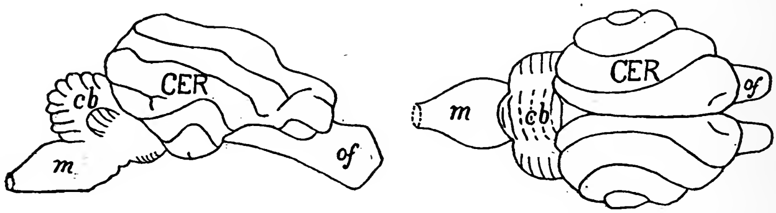
velopment continues when we pass to the brain of a mammal. The hemispheres of the cerebrum begin to look as if they were the whole brain. The optical lobes have indeed been so completely overlapped by the ever growing hemispheres that they have disappeared from sight.



A B

BRAIN OF A BIRD.

This continued growth of the same single ganglion—quite aside from a continuous, but less marked growth of all others—thru the various stages of evolution of the vertebrates illustrates a principle different, as we have said,

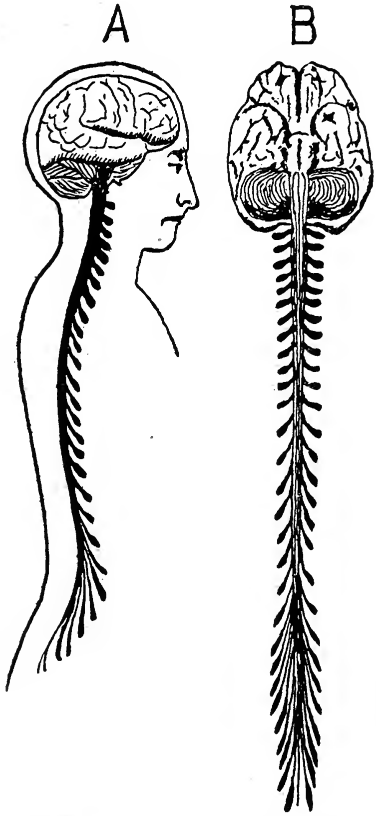


A B

BRAIN OF A LOWER MAMMAL.

from that which requires a bulkier nervous system for an animal possessing a greater number of sensory and motor points. This continued growth of a single ganglion can have a meaning only if the ganglion thus growing does not serve any peripheral points directly, but exclusively, or almost exclusively, indirectly. This growth can have a meaning only if the ganglion serves by interconnecting neuron groups already severally unified,—if it serves by unifying them into further derived groups, as illustrated by the scheme of our figure "group formation." The growth

of this ganglion, then, enables the animal more and more to react at any motor point to an excitation occurring at any sensory point whatsoever, without losing its indispensable local responsiveness.



THE NERVOUS SYSTEM OF MAN.

If we compare in our next figure the bulky part of the nervous system of man (that is, the part which can be cut out of the body with comparative ease) and the bulky part of the nervous system of a worm in a previous figure, we see that they are not unlike in appearance. However, to a nervous system like that of the worm man has appended the enormous mass of nervous tissue of the cerebral hemispheres (and, we might add, the considerable, tho lesser,

mass of the cerebellum) serving no other purpose than that explained in the last paragraphs.

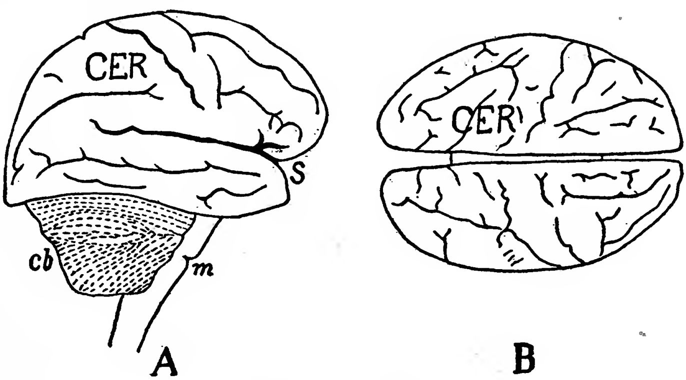
Along the two sides of the spinal cord there are two rows of ganglions somewhat separated from the cord. They recall to our mind the longitudinal series of ganglions serving the segments of the worm. Man, like all vertebrates, no longer is an animal consisting of so many segments, but his nervous system still preserves the reminiscences, so to speak, of an earlier stage of evolution. And the doubleness of the row reminds us that even in man, or especially in man, either side of the body often functions independently of the other. Many of man's activities, it is true, are of the symmetrical kind, requiring co-operation of the motor organs symmetrically situated. But not a few of his activities are one-sided. The reflex paths of a certain region of either side are therefore united in a ganglion before coming into connection with the nervous conductors of the spinal cord.

The body of man as we know it in life's activities consists essentially of only three longitudinal segments, the head, the upper part of the trunk with the arms, and the lower part of the trunk with the legs. One could deduce this, without knowing man's body, from merely observing the crowding of nervous tissue in the brain, the cervical region of the spinal cord, and the lumbar region.

In the next figure, showing the human brain without the cord, we see still more strikingly the enormous development of the cerebral hemispheres as compared with the cerebrum of the lower vertebrates shown in the previous figures. This ganglion, the cerebrum, has grown to such an extent that it hides practically all the other parts of the brain,—the other head ganglions which are relatively so conspicuous in the fish, the frog, and the bird. The cerebral hemispheres have in the mammals already fallen sideways over the other

original ganglions of the brain. In man they have further grown in the forward direction. They have done this, however, by first growing upwards and then falling in the manner of a stocking cap forward over themselves. This appears clearly in the view A of the brain of man. Thus on both sides the large Sylvian (named after a seventeenth century anatomist, Sylvius) fissure has been formed, at S in the figure. Only toward the back a piece of the cerebellum and, below, a part of the bulb or medulla are still left uncovered and observable as separate ganglions.

The cerebrum has become, as it were, the whole brain. Its growth, taking place in the brain exactly there where the most pronounced growth took place during the immediately preceding period of evolution, has every time served to make possible additional interconnections of the highest centers by still higher centers. Thus the growth has served to bring about an ever increasing possibility of the seemingly most unrelated sensory and motor points becoming functionally related. Thus almost any imaginable habit can become established during life, since its indispensable prerequisite is in existence, a nervous path—tho



BRAIN OF MAN.

long and roundabout and therefore of weak conductivity—from this or these sensory points to this or these motor points.

We need not suppose, however, that in this process of complication identical with unification, evolution has reached its highest possible mark. We should overestimate our race if we thought so. There are many indications that the functions of innumerable reflexes are still practically independent of the function of those which are already effectively unified by their connections with the brain and especially with the cerebral hemispheres. For example, it seems a hopeless task to try to train the Other-One so that, on telling him that his heart should beat a little more slowly, one can observe a decrease of the pulse rate. Foretelling in what direction evolution will proceed, is of course vain speculation.

Speaking of the evolution of the human race, one must not forget, however, that not all human individuals are alike. Great variations undoubtedly occur in the amount of the various functional properties, of which, as we have explained in the previous chapters, neurons are capable. Great variations are also possible anatomically. And these latter variations concern us particularly at this moment.

Not all individuals have the various higher and the very highest centers equally furnished with neurons. If there is a deficiency in the number of neurons here or there, many kinds of habits will establish themselves only in a very indirect and roundabout way, that is, very slowly, or even not at all. We speak of people whose capacities for establishing habits are limited, in general as being less intelligent. More about the meaning of the "intellect" or "intelligence" will be said in a later chapter. At this moment it suffices to hint at the fact that intelligence and lack of intelligence have their anatomical foundations.

That there should exist a rather definite relation between the amount of conductive tissue present in the brain and the "amount of intelligence" or the quality of intelligent

behavior of which a person was capable, occurred to those familiar with the anatomy of the brain long ago. The phrenologists worked on the problem unsuccessfully. During the nineteenth century the problem assumed the simpler form of an estimation of an animal's or person's general intelligence on the basis of his brain weight.

Of course, after an animal's brain has been removed from the skull and weighed, that individual animal is dead. Knowledge of its former intelligence is then of little practical value. But if by weighing many brains of a species and determining the average brain weight of the species one could discover the average intelligence of that species, this would still be of considerable practical value. For example, in choosing a watch dog for our house or herd, we should not hesitate, other things being equal, to take our choice between two species if the average intelligence of one of these groups could be proved to be greater than that of the other.

With respect to human beings there are many similar questions concerning group problems, that is, social problems, on which such a measurement, if it existed, of the average intelligence of a group could shed light. There are traditions, customs, and even laws, which are based on the belief of an innate difference of intelligence between the various human races. And there are traditions and laws relating to the two sexes which are wholly or partly based upon the belief of an innate inferiority of one of the sexes. Since the beginning and still more since the middle of the nineteenth century these problems have attracted the attention of not a few careful investigators.

A large number of brains of men and women have been weighed. It has been found that the average male brain is somewhat heavier than the average female brain. In making the comparison, the investigator chooses, of course,

the brains of as homogeneous a class of people as possible. The following values are taken from such an investigation made years ago in an English workhouse. The average weight of adult females was found to be 1212 grams, and the average of males 1335 grams. If absolute brain weight is an indicator of intelligence, the advantage is here decidedly on the side of the males.

The conclusion just mentioned has several times during the nineteenth century been drawn by investigators. However, toward the end of the century the relativity of such measurements became sufficiently recognized, so that investigators measured, not only the brain weight, but also the body weight of the same individuals. We ought to be aware of the fact that large animals, like cattle, have and must have a more voluminous nervous system than small animals, like rats, without being on that account more intelligent.

Another investigator therefore measured also the body volume in the simplest and most natural way, by weighing it, as he determined the brain volume simply by weighing it. He found as average brain volumes for females 1224 grams and for males 1431 grams. As average body volumes he found from the same individuals for females 54.8 kilograms and for males 66.2 kilograms. These data will form the basis of all our following considerations. Having the average weight of the brain and of the whole body, one easily computes the percentage of the brain volume within the whole body volume. This is found to be 2.23 in females and 2.16 in males.

It is interesting to note that those who were particularly interested in drawing practical conclusions from determinations of male and female brain weight, never drew any conclusions from the values last mentioned. If formerly the absolutely larger brain of males was a "scientific proof"

of the superiority of male intelligence, why were these values no "scientific proof" of the inferiority of male intelligence? One wonders if the fact that those drawing or not drawing these conclusions were men, has any significance in this connection.

A convenient way of making the comparison is to divide the value found for females by the value found for males. In order to avoid decimals, let us choose as denominator a thousand rather than one. Then, if the numerator is larger than 1000, it speaks in favor of the female sex. If it is smaller than 1000, it favors the male sex. A comparison of the absolute brain volumes thus gives us the following quotient:

$$\frac{\text{Female Brain}}{\text{Male Brain}} = \frac{855}{1000}$$

A comparison of the brain volumes relative to the body volumes gives us the following quotient:

$$\frac{\dfrac{\text{Female Brain Volume}}{\text{Female Body Volume}}}{\dfrac{\text{Male Brain Volume}}{\text{Male Body Volume}}} = \frac{1033}{1000}$$

We see here that the pendulum, so to speak, has swung to the other side.

Toward the last few years of the nineteenth century the doctrine that the nervous system was a conductive connection between the sense organs and the muscles and not the mysterious seat of any autocratic governing power, began to be fully and generally accepted even by those who were specially interested in the problem of the comparison of brain measurement and intelligence measurement. They began to recognize the importance of the fact that for "intelligence" certain sense organs are of less, other sense

organs of the greatest importance, and that the latter are not distributed all thru the body, but lie mainly on or near the surface of the body. Roughly speaking, one may say that the number of these here significant sensory points increases proportionately with the increase of an animal's surface.

Of the skeletal muscles it may be said that they form the bulk of the whole body. The nervous system, in so far as it serves these muscles, may be regarded as serving the body well enough if its increase keeps step with the increase of the body volume. If the body volume increases out of proportion to the brain,—too bad for the animal's intelligence, as in the case of the human males in the last quotient.

But in so far as the conductive tissue serves the surface sense organs, one must say that it serves them well enough only if its volume keeps step with the increase of the size of the animal's surface. Now if we are not interested at all in the absolute size of the body surface, but only in the question how a small and for all its parts proportional increase in an animal's size would increase its surface, we do not have to take any new measurement, but have merely to make a computation. As a matter of fact, the ratio of surface to surface is all we are interested in. The surfaces separately do not concern us. And the ratio of the surfaces can easily be computed, when we know the ratio of the volumes. It is the square of the cube root of the latter.

The above stated quotient, which yielded the ratio 1033 to 1000, can also be written thus:

$$\frac{\text{Male Body Volume}}{\text{Female Body Volume}} \times \frac{\text{Female Brain Volume}}{\text{Male Brain Volume}}$$

Now we know that the ratio of these body volumes is 1208 to 1000, the same as 66.2 kilograms to 54.8 kilograms.

The square of the cube root of 1.208 is 1.134. Then we get the following comparison of the brain volumes relative to the body surfaces:

$$\frac{\text{Male Body Surface}}{\text{Female Body Surface}} \times \frac{\text{Female Brain Volume}}{\text{Male Brain Volume}} = 1.134 \times \frac{855}{1000} = \frac{970}{1000}$$

We see here that the pendulum has again swung back, in favor of the male. But at the same time we notice that each time the numerator differs less from a thousand than the last time, speaking more in favor of an equality of the sexes in intelligence. It has changed from 855 to 1033 and back again as far as 970.

Now, really, the surface alone does not any more than an animal's volume alone determine how much nervous tissue is needed to serve the whole animal well. Considering the volume alone, the value of the quotient was in favor of the female. Considering the surface alone, the value of the quotient was in favor of the male. Considering both, the value must lie close to 1. That is, neither sex has any advantage over the other. About the same conclusion follows from considering all three quotients.

It seems strange that attempts should ever have been made to deduce an intellectual inferiority of either sex from anatomical features. Our understanding of the functioning of the nervous system, notwithstanding the progress which has been made during the last hundred and fifty years, is still extremely imperfect. We are, and ought to be, very elated whenever we discover that our theories of nervous functioning find an additional support in those facts of the Other-One's behavior which we have newly discovered or to which we have only recently learned to pay proper attention. It is sheer folly to proceed the other way and to apply to real life conclusions from our theories of nervous functioning combined with our meager anatomical knowledge. If we draw conclusions for our own instruction mere-

ly, in order to test our theories, this is all right. But to publish such deductions and to invite, or thru the lack of proper warning even only to permit, the public to regard them as facts in which we men of science believe, is not very far from criminal negligence.

The public, which unavoidably consists of groups, of which the two sexes, the various races, and the different nationalities are the most ponderous examples, is always ready to nourish its prejudices by so-called "scientific proof." But forms of behavior—and "intellect" or "intelligence" are nothing but forms of behavior—can not yet be deduced from a study of the nervous system more perfectly than they can be discovered by a direct study of the Other-One's behavior, by simply watching with due care his conduct.

That men and women are different, is well enough known. In so far as their organisms function differently, their inherited forms of behavior must be different. In so far their nervous systems, too, must be different. But in so far as their organisms do not function differently except by accidents of habits acquired—and this applies to every case where we have the right to speak of intelligence—it would be nothing short of a miracle if nature had equipped them thru heredity merely because of their sex difference with an important inequality for the performance of the same work.

Even if it should be true—it would be hard to prove and thus far has not been proved—that, no matter what the environment, the greatest geniuses of mankind could not be matched by any which might arise within the female sex, that argument would support no discrimination between the sexes by law and custom. Of course, no one can argue for an equality of things which are different, and this is no argument asserting that the two sexes are not

different. The argument is merely that brain measurements do not prove any intellectual difference between the sexes. And otherwise, by direct observation of their behavior under equal and varying conditions, it has not been proved either.

The comparison between brain weight relative to body volume and body surface on the one hand and observable intelligence on the other can be attempted with animals in the same manner of computing the quotients as we have computed them for the two human sexes. As men and women do not have bodies of essentially different proportions, so animals in general do not essentially lose their proportions when changing in the course of evolution to smaller or larger sizes. Think of different dogs, for example. Or think of the deer and the roe. Or think even of a mouse and a kangaroo. The proportions are nearly enough the same to compute the ratio of the surfaces directly from the ratio of the volumes, that is, of the weights.

Let us give the three quotients in the case of an English terrier and a Newfoundland dog. Their body weights are 5300 grams and 38345 grams. Their brain weights are 69 grams and 120 grams. The three quotients are:

$$\frac{575}{1000}, \quad \frac{4160}{1000}, \quad \frac{2151}{1000}.$$

The first one favors greatly the Newfoundland, the second one favors enormously the terrier, the third one favors again the terrier, but much less than the second. We can leave it to the reader to decide which of these two breeds is the more intelligent, and how this follows from the quotients based on comparison absolute, relative to body volume, and relative to body surface.

CHAPTER VIII

THE OTHER-ONE'S MOST INTERESTING REFLEXES AND INSTINCTIVE ACTIONS.

Any particular reflex is defined by stating where its sensory point and its motor point are located in the Other-One's body, for example, in the palm of the hand and in the muscles bending the fingers of the same hand. In certain cases it is of course necessary to state, either instead of or in addition to the sensory point, the quality of the stimulation, for example, a shrill tone. And it is also necessary in certain cases to state the qualitative nature of the muscular response, for example, scratching, or in another case pressing something down. But generally speaking a sensory point and a motor point determine a definite reflex.

Since the reflexes are very numerous, any science concerned with them very naturally desires to classify them. One could classify them with reference to the different sensory points. But this classification would be of anatomical rather than of psychological interest. One could classify the reflexes with reference to the muscles acting. But this classification would be anatomical and physiological rather than psychological. A psychological classification will have to be based chiefly on the service rendered by the reflexes in the Other-One's life.

It is well, in this classification of the fundamental and therefore inherited forms of behavior, to make no distinction between reflexes and instinctive activities. A classification based on services rendered need not take into account the relative complexity of the inherited nervous functions.

In the very first chapter we had to point out that all animals need locomotion in a straight line in response to

the stimulus of lack of food. We added later to this form of behavior as a second one of equally fundamental importance that of changing the direction of the body axis in response to stimulation coming from an obstacle lying in the animal's path. We must now add a third fundamental form of behavior, that of making a localizing movement. A simple illustration of the localizing reaction is found in the classical experiment usually performed in a beginner's course in physiology. If a sour substance is placed in contact with the skin of a decapitated frog, that foot of the animal which can most easily reach the spot, moves to the irritated spot,—as the spectator would probably say "in order to wipe off the irritating thing."

The Other-One is equipped by Nature with such reflexes that he acts in very much the same way as the decapitated frog does. If a pin pricks his left shoulder, the right arm moves until one of its fingers touches the point stimulated. If the right shoulder is pricked, the left hand moves toward it. If the upper lip is tickled, the lower lip or the tongue moves toward the spot. If the left ankle is irritated, the right foot goes towards it. In every case that part of the body which is most movable in the direction of the stimulated spot, moves toward the spot.

What becomes of the localizing reflex in those senses in which the stimulating object need not itself approach the skin, but may and usually does act upon the body surface from a distance? The most important sense organ of this class is the retina of the eye. It is clear that when the Other-One stands before an apple tree and the red light coming from an apple stimulates a certain point on the lower half of his retina, it could do him no good to have his finger localize that point on his retina. The finger could not touch the retina, but only the cornea, the frontal layer of the eyeball. Even if it could touch the retina, however,

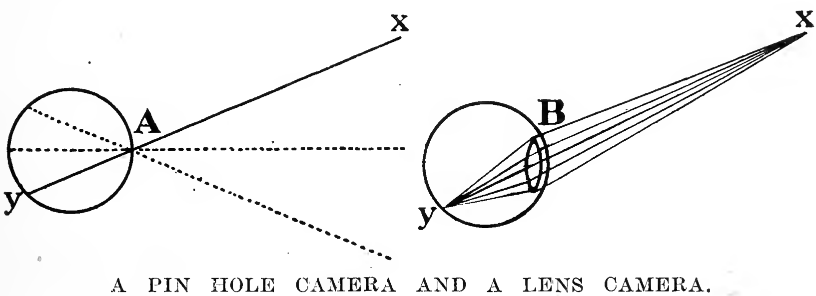
no advantage could result comparable to that of wiping off or killing an insect when the finger localizes a spot on the skin. An advantage could result only from approaching the object from which the stimulus emanates, in this case the apple. If the Other-One's finger approaches it enough to come in contact with the apple, this may cause the apple to fall and thus to become available to him as food.

When we introduced as the third fundamental form of animal behavior that of making a localizing movement, we might at once have distinguished, and we do now distinguish, two subdivisions, (1) localizing a stimulated point on the skin by that part of the body which is most movable in the direction of the stimulated point, and (2) localizing a distant point from which a stimulating effect emanates by that part of the body which is most capable of approaching along the line from the animal's body to that point of emanation. As in the first of these subdivisions of the localizing reaction, so in the second, the animal must be equipped by Nature with neuron chains, reflex paths, leading the excitation from the sensory point stimulated to that motor point (that is, set of muscles) which makes the particular localizing movement mechanically possible.

Of all the senses in which we find reflex responses of localizing the point from which the stimulating effect emanates, the visual sense is by far the most important. We have already referred to the reflex functioning in this case and shall go now more into the details. The refracting transparent media of the eyeball, the cornea and lens especially, break the rays of light so that the whole bundle of rays emanating from an external point is collected again on the retina in approximately a single point. The effect of the cornea and lens, which really form a system of two lenses strengthening each other, is—apart from the intensity of the light admitted to the interior of the eyeball—very much

the same as if the eyeball possessed no refracting media at all, but consisted of a hollow sphere having a minute hole in front, like a so-called pin hole camera used for certain kinds of photographic work where, as with distant landscapes, light intensity is unimportant and long exposure entirely feasible.

Whenever we have to illustrate by a diagram any function of the eyeball, we shall always represent the path of the light as if the eye simply had a pin hole in front (A in our figure) instead of a lens (B in our figure), since this simplifies the drawing immensely. It makes any figure more quickly and easily comprehensible because there is only one line for each actual bundle of light rays. And it permits equally well the explanation of all those facts in which we are interested as psychologists. It is clear from the figure that all the lines of light, for example, xy, cross in the pin hole. The light coming from above falls on the lower region of the retina, that coming from the left side falls upon the right side of the retina, and so forth.



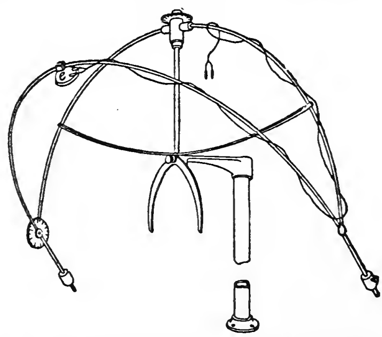
A PIN HOLE CAMERA AND A LENS CAMERA.

Imagine now again that you have been appointed assistant to the Creator, and that you have been given the task of constructing a nervous system enabling the Other-One to perform the localizing reaction when light strikes his eye. You surely would connect by a reflex path any point on the lower region of the retina with those muscles which are capable of moving the arm, or whatever you

choose as the most convenient movable limb of the body, upwards. The lower the point on the retina which is stimulated, the more you would lead the reflex path in the direction of those muscle fibers which are capable of throwing the arm still farther up. Your task is no more difficult than that of the line man of a telephone company.

Exemplifying the second form of the localizing movement—localization in the direction from which the stimulating effect emanates—we spoke of the visual sense. It must not be inferred, however, that this is the only sense organ in whose function this localization plays a role. A very important kind of localizing is that applied to a sounding object. The Other-One's right ear is connected by a reflex path with those muscles which move a part of his body most easily to the right; that is, generally, those muscles which stretch the right arm toward the right. His left ear is connected with those muscles of the body, especially those of the left arm, which may bring about a movement to the left.

One may get a more concrete idea of the working of this reflex by performing a rather simple experiment with the Other-One which consists in localizing an infinitesimally



APPARATUS FOR LOCALIZING TELEPHONE CLICKS.

brief tone. Seat him comfortably in a chair, with his eyes closed. Let him, after the usual "ready" signal, hear a

telephone click and ask him where it was located. Of course, with a person you need not (although you may) use in this experiment the original reflex of pointing in this or that direction. Instead of that you let him tell you in words where the click seemed to be located. You use for the telephone a limited number of positions, say, front, back, left, right and the four intermediate positions on the same level, that of the ears. You may add as a ninth position that of above the head of the Other-One; and still further positions if you like, but definite ones to be agreed on beforehand.

When you analyze the results of the experiment you find that the (comparatively few) errors made by the Other-One never consist in a confusion between left and right. The fact that the total number of errors is small, is clearly due to the fact that in addition to the reflex here in question the Other-One utilizes various other reflexes, modified into habits, for his reaction, that is, for telling the direction of the sound. But the fact that there is once in a while confusion between the other directions, but never between right and left, illustrates the working of the localizing reflexes of the left and the right ears.

In the sense of smell we have localizing reflexes much like those in the sense of hearing. They do not play a great role in human life, because man does not use the sense of smell much for any purpose. The greatest use which can be made of the sense of smell consists in its application to the ground and the things on the ground. Animals can easily use this sense in this manner by simply lowering the head, even while running at a considerable speed. Man, in his usual erect position, cannot easily apply his sense of smell to the ground and the things on the ground. The result is that the species man makes so little use of this sense in comparison with animals, for example with dogs, which

can trace another animal on the ground hours after it has passed. Only extraordinarily strong (relatively strong) odors affect man.

For many animals, however, these reflexes are of great usefulness, especially for those whose nostrils are more than man's nostrils exposed sidewise. A volatile substance present in, and moving with, the air, has then a chance to stimulate the sensory points of one side more strongly than those of the other side and to call forth a localizing reflex movement dominatingly toward one side of the body.

As for localizing sound, so for localizing odors the Other-One and animals, too, actually use, not only the localizing reflex, but also localizing habits derived from entirely different reflexes. We shall return to this fact on a later occasion when these other reflexes are discussed.

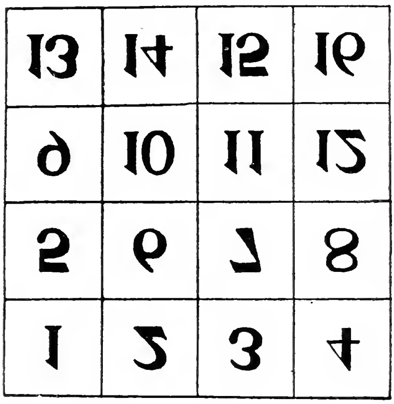
But there is this difference between the fact that the Other-One has two ears and two nostrils and the fact that he has two eyes. With respect to the localizing movement which we have just discussed it is a mere luxury to have two eyes. One would be sufficient. The second is there merely for the sake of insurance in case the one should get broken. On the other hand, the proper localizing reflex would be utterly impossible if the Other-One had one ear only, one nostril only. Either ear is to be compared, not at all with either eye, but with a single point (of the thousands of sensory points) of a single eye. Localizing with the ear or nostril, where there are virtually not thousands, but only two sensory points, is accordingly restricted to one dimension; localizing with the eye is extended over two dimensions. (But these remarks refer only to the localizing reflexes. Localizing habits not derived from the localizing reflexes and being of more than two dimensions will be discussed later, as already promised.)

We have a chance to learn in this connection that problems—pseudo-problems, we should prefer to say—which, if the old-fashioned psychologists were not puzzled by them, at least interested them enough to be discussed and "solved" by them, entirely disappear and, because they do not exist, call for no solution whatsoever. The older psychologists used to raise the question, in all seriousness: "Why is it that, altho in the eye (as in a photographic camera) the picture stands upside down, we 'see' the image upright?" The old-fashioned psychology used to ask what we "see" or what our selves are "conscious" of. But we ask in this book what the Other-One "does." When the lower region of his retina is stimulated, his arm moves up, because Nature gave him a reflex path as already described. There is no further problem left for solution, unless you call "a problem" the mere fact that Nature runs the reflex paths thru the Other-One's body from such points to such points that the stimulating object is "localized," and not to such motor points that the resulting movement is wasted because it fails to localize the stimulating object.

A simple experiment demonstrating the strength of the localizing reflexes can be performed as follows. Think of a card on which the numbers from 1 to 16 are printed consecutively in four lines. The card is transparent. You turn it over vertically, not like a book page, and look at the numbers from the reverse side. The numbers appear then as in our accompanying figure.

Now place this card, as it appears in diminished size in the figure, before the Other-One together with sixteen little squares which you have obtained by cutting another card, exactly like this, along the lines. Make him look at the card on the table and at the little squares in his hands thru a large enough (four or five inch) total reflection prism

placed so that it turns everything upside down and downside up. Then all the numbers appear in his field of vision normal and those on the large card appear arranged in the regular order from the upper left to the lower right corner. Now make the Other-One distribute the squares in proper position over the card. He is thus obliged to break up the reflex and substitute the habit of moving his hand upwards when the upper region of the retina is stimulated, downwards when the lower region of the retina is stimulated.



CARD USED IN BREAKING UP THE LOCALIZING REFLEX

If we take the time required for each successive distribution of the squares over the card, we have all the data for the construction of a curve of habit formation. This is interesting from the point of view of a previous chapter in which we discussed the learning process. But the reason for mentioning this experiment in the present connection is the one already referred to: Nothing could impress upon us more strikingly the existence of the localizing reflex than the performance of an experiment in which our task consists in breaking up this reflex, changing it into the reverse reaction.

One of our statements concerning the localizing reflexes must be enlarged. We said that it is the most readily movable part or limb of the body which performs the localizing

movement. Under certain conditions, however, it may happen that no part of the body can approach the point to be approached more easily than, or even as easily as, the body in its totality. In such a case Nature may make provision for a localizing reflex consisting in locomotion. Generally in such a case there is first a turning movement until the animal faces the source of the stimulus, and subsequently forward locomotion in this direction. We remember at once the case of the moth already discussed.

We have thus far enumerated three forms, fundamental and inherited, of animal behavior. The first was locomotion of the animal in a straight line in response to the stimulus of lack of food. The second was turning in response to an obstacle lying in the path. The third was localizing a stimulus on the body surface or the source of an emanating stimulus in a certain outward direction. It should now be added that the localizing movement may be either positive or negative. That is, the reflex movement may be a stretching of a limb or appendix of the animal toward the source of the stimulus; but it may be, altho this is probably a rarer case, a bending and consequently a withdrawal of the appendix from the source of the stimulus. In either case the movement would be along the same line, but it would be either in one or in the opposite direction. The distinction must therefore be made of a positive and a negative localization. This distinction becomes especially impressive when the localization is of the nature of a locomotion of the whole body: The animal either approaches the stimulus or moves away from it. The latter, the negative localization is obviously quite indispensable in the presence of certain stimuli,—of all those which are universally deleterious.

Because of its great importance this negative localization deserves to be counted as a special class of reflexes. Let

us therefore count "positive localization" as the third and "negative localization" as the fourth class of fundamental forms of behavior.

We now have to add a fifth fundamental form of behavior, that of grasping. We have pointed out in our discussion of the positive localizing reflexes that one of their services consists in providing the organism with food. If the Other-One's finger approaches an apple on the tree enough to come in contact, the apple may fall and thus become available as food. But it becomes food still more certainly if it is grasped and carried toward the mouth. The grasping reflexes, while serving still other purposes, may therefore be regarded chiefly as the natural companions of the positive localizing reflexes.

In describing a grasping reflex, as in describing and defining any particular reflex, we have to state the nature of the stimulus, the sensory points on which the stimulus acts, and the motor points which respond. The motor points of the body are to be found in this case in the flexor, that is, bending, muscles of any animal's limbs. The sensory points are to be found in the skin on the concave side of the same limb which bends, but also in other sense organs, for example, the taste organ. In the Other-One the sensory points of this reflex are located chiefly in the palm of the hand, including the corresponding side of the fingers, and in the sole of the foot. The stimulus is gentle pressure. Strong pressure does not serve this, but other reflexes. Tickle the sole of a sleeping person, and the limb bends in all its joints. That is, the toes bend and the bending of the leg in the hip and knee joints brings the foot closer to the trunk of the body.

When it happens that an apple stimulates the eye, and the localizing reflex causes the arm and fingers to approach the apple so that the inner surface of the fingers or the

palm of the hand is gently stimulated by the contact, the bending fingers surround the apple and the bending of the arm in the shoulder and elbow joints brings the apple closer to the body, very likely into the neighborhood of the mouth. Thus the localizing and grasping reflexes together accomplish the fulfillment of an important condition for the continuation of the Other-One's life.

A sixth class of fundamental forms of behavior, for which Nature has provided in the nervous system many reflex paths, is that of adjusting the sense organs. Perhaps the simplest example of adjusting the sense organ so that its usefulness will be greatest, is to be found in the Other-One's cutaneous senses. Let us select from them for this discussion the sense of pressure on the skin. We shall have to give in the next chapter a fuller discussion of the fact that the discriminative capacity of the skin is greatest, that is, that the threshold is smallest, where the curvature of the surface is greatest, that is, at the finger tips and the lips.

Accordingly, when the Other-One must use his pressure sense, as when he has to find his way in the dark, or when he has to pick up food in the dark with his teeth (he is not supposed to have any particular table manners), it is of great advantage to him to stretch out his fingers so that the things among which he has to find his way come in contact first with his finger tips, or to get the food which is to pass into his mouth first in contact with his lips. It would be far less advantageous to him if the contact occurred on his knuckles or his elbow or his shoulder or his cheek, where his ability to discriminate is relatively deficient.

The Other-One does not expose his lips to stimulation so much as he does his fingers. But animals which have no discriminative sensibility on those extremities which cor-

respond to the Other-One's finger tips, expose their lips to stimulation in a similar manner as the Other-One does his fingers. Remember how a horse or rabbit applies its lips before taking anything into its mouth, or how an elephant uses the tip of its trunk toward a similar end. In all these cases the animal adjusts its cutaneous sense organ by exposing to stimulation that part where the threshold of discrimination is smallest, the sensibility greatest.

Let us now consider the adjustments of the Other-One's visual sense organ. There are three, (1) the adjustment of the direction of the axis of the eye, (2) the adjustment of the size of the pupil, (3) the adjustment of the curvature of the lens.

The discriminative sensibility is much greater in the center, the fovea (pit), of the retina than in its peripheral parts. If an object stimulates a peripheral point on the retina, the eye muscles surrounding the eyeball—of which there are six, three pairs—contract reflexly in such a manner that the axis approaches the direction of the beam of light. The result is that that part of the retina is exposed to the stimulation where the discrimination is greatest,—the central part, the fovea. The service of this reflex is therefore entirely like that of the adjusting reflex in the pressure sense of the skin.

Since both eyes are adjusted in this way, the result is that the axes of the eyes form an angle, the so-called angle of convergence, which is the more acute the greater the distance of the object whence the light emanates. When the angle of convergence is very small, there is naturally very little difference in the degree of contraction of the antagonistic muscles of each eyeball. The larger the angle, the more unequal is the degree of contraction of the antagonistic muscles on the two sides of the eyeball. This is in no way related to the present discussion of the fact that the

adjustment of the sense organs is an important class of reflexes. The relation between this angle and the muscular tension is mentioned here because we shall in a later chapter have to refer to this angle; and it will then not be necessary to explain again to what reflexes the angle of convergence owes its existence.

The second adjustment mentioned is that of the size of the pupil. In front of the lens is located a diaphragm, the visible part of which we call the iris, and in accordance with the color of which we call an eye blue, gray, brown, etc. The hole of the diaphragm, which appears dark because of the dark cavity behind it, is the pupil. The pupil is the larger, the weaker the general illumination of the objects of which the environment consists. When the retina is more stronglv stimulated, the response is a contraction of the pupil.

This means, then, that the stronger the outside light is, the smaller the fraction of it admitted to each point of the retina of the eye. In consequence, the stimulation of the retina does not increase in proportion as the light increases, but much less. The range of the light intensities under the influence of which the Other-One's retina can properly function is thus extended, for the maximum excitation beyond which the retina could not properly function, is not reached so soon.

The third adjustment of the eye consists in the accommodation of the lens. Certain muscle fibers located within the eye ball change the curvature of the lens in such a manner that the lens is the flatter the greater the distance of the object stimulating the eye. The optical effect is this: in spite of the varying distances at which the object may be, all the light emanating from any point of the object is again invariably collected in a point on the retina and not diffused over an area. Since we call such a point—on the

object as well as on the retina—a focus (hearth, fire place), the adjustment of accommodating the eye to the distance is sometimes also called focusing. Accommodation, however, is the preferable term, because it has always been the customary one among physiologists and psychologists.

The reflex in question may then be described as follows. Only when the retinal elements are stimulated in such a manner that those stimulated with the same qualitative effect of excitation form groups on the retina with sharply defined outlines, is the tension of the accommodating muscles left unchanged, whatever it happens to be. While this description of the reflex has a somewhat negative form, it is more accurate than any equally brief positive description could be.

If these areas of retinal elements of like excitation do not possess sharply defined outlines, but encroach upon each other, overlap, the muscles of the accommodating apparatus begin to undergo a change of tension, accidentally either in such a way that they flatten the lens or in such a way that they cause the surface of the lens to bulge, until it happens that the group outlines referred to become so sharp that the accommodating muscles cease to be affected, that they remain henceforth in the unchanged state of tension mentioned in the preceding paragraph. This places upon the architect of the nervous system a difficult problem of architecture and engineering. How Nature has solved it, we do not yet know.

In the auditory sense organ we find again three kinds of reflex adjustment. One is that thru action of the muscle which is called the tensor tympani. It is of physiological rather than of psychological interest and therefore here but briefly mentioned.

Another adjustment is the change in the direction of the external leaf, which is popularly called the ear altho it is a rather insignificant part of the auditory equipment. We

know how such animals as horses and donkeys move their ears, with the result of catching more of the sound waves passing thru the air, in accordance with the direction of the sound. Human beings make so little use of this reflex that those who in adult life exhibit even a trace of it, are regarded almost as curiosities.

The most important one in the Other-One's life of these three adjusting reflexes of the auditory organ is that of turning the head until its median plane, the plane which divides the head into two symmetrical halves, coincides with the direction of the sound waves. The exact working of this reflex can be described more easily than it may at first seem. Physical investigations (especially those of G. W. Stewart) have shown that the total sound effect, that is, the sum of the two sound effects in the two ears physically measured, assumes its greatest value when the source of sound is located in the median plane of the head; and that the total sound effect decreases rapidly with the increase of the angle between the median plane and the direction (positive or negative) of the sound. The reflex, therefore, works as follows.

As soon as the auditory organ is stimulated, the muscles of the head begin to turn the head in either direction. In what direction they pull at first, we may regard as an accident. If the total sound effect decreases, at once the muscles antagonistic to those that were pulling, begin to pull the head around in the opposite direction and continue to do so until there is again a decrease in the total excitation of both auditory organs together. Naturally this happens directly after the median plane has swung thru the line of the propagation of the sound. Now the first set of muscles again reverses the motion. But the ultimate effect must then quickly be that of fixing the median plane so that the direction of the sound coincides with it.

Thus far the consequence might be that the Other-One either faces the source of sound or has it in his back. But since the two ear leaves interfere with the sound in such a manner that its effect on the organ is greatly diminished when it comes from the back, there is only one absolute maximum for the sum of the two excitations in both ears together, and that maximum occurs when the Other-One faces the sound.

You can easily convince yourself of how much difference it makes whether the Other-One has such leaves attached to his head or not, even tho he cannot direct their openings toward the sound as many animals can. Of course, we cannot cut them off for this purpose, but we can easily prove it without any such operation. Just let the Other-One hold his hollow hands before his ears, thus counteracting the effect of the two natural leaves by two much larger artificial ones. Let him try it while he is listening to you speaking behind him. Ordinarily your words would then be difficult to catch. At once he tells you that he can hear you much more distinctly, quite normally. Let him try it while you are speaking before him, and he will tell you that he can hardly understand you any longer.

The advantage of this reflex of turning the head is both a direct and an indirect one. The direct one is that of the best possible exposure of the total auditory sense equipment. That is, it is a reflex response to sound resulting in an adjustment of the sense organ of sound. But incidentally it is at the same time an adjustment of other sense organs. For example, the eyes are now better exposed to the object sounding in case this object should act also as a visual stimulus. The same indirect advantage of better exposure may result to the olfactory sense, the cutaneous sense of the hands, and other senses.

The physicists, as just stated, discovered that the total excitation of both our auditory organs combined is greatest, for physical causes, when the source of sound is in the median plane and in front of the head. With much less physical insight everyone knows that for a person who has only one ear in functioning condition, the excitation reaches a maximum when the source of sound is on the side of the head, and fronting the auditory organ which is intact. The one-eared person therefore reflexly adjusts his sense organ by turning the head until the excitation is strongest when the source of sound is located opposite his healthy ear or, because of the influence of the ear leaf, a little forward of that position. If he then acquires the habit of turning his head about ninety degrees in a particular direction he obtains by habit the advantage of exposing the other sense organs (visual, cutaneous, etc.) which the normal person obtains thru the possession of the reflex adjustment of the organ of hearing.

When the one-eared person has thus learned to stretch out his arm with the result of bringing his fingers in contact with the sounding object, the movement deserves to be called a "localizing habit" comparable to the auditory "localizing reflex" which we have mentioned among the localizing reflexes in general. This leads us to a further brief consideration, previously promised, of the manner in which reflexes which are not originally localizing reflexes may become localizing habits, that is, may be used as if they were localizing reflexes. The reflex actions which serve directly the purpose of an adjustment of the sense organs, serve with special ease this additional purpose.

A typical example is that of turning the head until a sound stimulus is located in the median plane of the head. In this location, we remember, the total effect is greatest, provided also that the head faces the stimulus. If now

the organism has been furnished by Nature also with reflexes which adjust the position of the whole body to the position of one of its parts, in this case the head, the body, moving forward, will move toward the source of the sound.

This indirect localization of sound by means of the reflex which serves directly the adjustment of the sense organ happens to become of greater importance in actual life than the direct localizing reflex. The reason for it is not difficult to see. This indirect localization is far more exact, being applicable to any angle and not confined merely to localizing on the right or the left side of the body: It is two-dimensional, that is, not merely one-dimensional and distinguishing only the directions in the single dimension right-left. Nevertheless, the direct localizing reflex is not superfluous, for it alone is available when the sound to be localized is of such short duration that no adjusting head movement can be completed while the sound lasts. Therefore the experiment of localizing a telephone click (intentionally not a prolonged tone) is a test of the true localizing reflex.

In the olfactory sense we find two reflex adjustments. One is similar to the auditory adjustment last discussed. That is, the frontal part of the median plane of the head is made to coincide with the location of the volatile substance from which the stimulus emanates. The other adjustment consists in breath control. When the air is drawn in forcefully thru the nostrils (in extreme cases we call this sniffing), the sensory surfaces in the nasal cavities are exposed to more of the stimulating molecules than they would otherwise come in contact with during a unit of time. If breathing is stopped altogether for a short time, very few molecules of the stimulating substance will be able to penetrate during this time far enough into the nasal cavities to reach the sensory surfaces.

Just as the auditory adjusting reflex last mentioned may be used, by habit, for sound localization, so the olfactory ad-

justing reflex may be and is developed into a smell localizing habit. For example, we see the Other-One, blindfolded, turn his head and body until the excitation in his nasal cavities is strongest, and then reach for the bunch of flowers which we hold ready for him.

Six classes of fundamental forms of animal behavior have now been distinguished. (1) Locomotion in a straight line in response to lack of food. (2) Turning the body axis sidewise in response to an obstacle. (3) Positive localization in its two forms, on the body surface and in the direction of a distant stimulus. (4) Negative localization. (5) Grasping. (6) Adjustment of the sense organs.—A seventh class is to be added to this list. Animals respond to certain stimuli, sometimes internal, sometimes external stimuli, by the contraction of certain muscles whose function is of no direct consequence to the animal itself, but affects other animals by stimulating them to act,—often animals of the same species, but perhaps no less frequently animals of a different species. Since this is what we call in the social life of human beings "signaling," let us call this class the signaling reflexes.

A few, but very diversified examples of the signaling reflexes are the lighting up of a fire fly, the squeezing out of a black liquid from the ink bladder of a cuttle-fish, the communication of a shock by an electric eel, the crowing of a rooster, the barking of a dog, the spreading of its tail feathers by a pea-cock. These reflex activities, we said, are to affect other animals by stimulating them. How, by what reflexes, these other animals respond to this kind of stimulation, does not directly concern us here. So much is clear, that if no other animals are present, or these other animals fail to respond by their own reflexes, the former reflex actions are completely wasted. Neither of these cases is rare. We have to say more of this waste later.

It is clear, however, and therefore may be stated at once, that these responses of the other animals are chiefly their localizing reflexes, positive and negative. The signaling, that is, is of the nature of attraction or repulsion. It is of great importance in the sexual life of animals; but also in innumerable other forms of co-operative activity. And it is of hardly less importance in the social, but not co-operative, —or call it anti-social, if you prefer—activity which goes under the name of fighting.

The stimuli calling out the signaling reflex actions in the first animal vary so much from species to species that very little can be said concerning them which would be true in general. However, they are, as already stated, either internal or external. The most common kind of external stimuli of the signaling reflexes are visual, for example, the light of the early morning which makes the rooster crow; but especially the visual appearance of the whole other animal in various attitudes. Smell and sound stimuli originating in the other animal are probably not of much less importance. The internal stimuli are, under special conditions, organic and secretory stimuli resulting from the physiological processes going on in the body itself. They play their role and become effective even when there is no other animal in the neighborhood upon which the signal resulting from the reflex could have any effect. But, of course, there always might be one not too far away.

Let us turn now to the motor aspect of these reflexes. It is plain that the most indispensable kind of signaling is that thru a distance. However, signaling may occur by contact, acting on the cutaneous sense. Handshaking is a conventional form of signaling by contact. It is a modification of such reflex crowding together as may be seen with rabbits, or with chickens sitting on a roost, where none wants to be at the end of the line or to be alone, but every new-

comer tends to crowd in between two already close together. By handshaking the Other-One signals to us that he is to stand together with us, literally and figuratively.

But there is a greater need for signaling thru a distance. When the other animal or person is in my neighborhood, he is exposed to the same stimuli to which I am exposed, and in reacting to them we may co-operate. But when he is at a distance, I have to call him, to signal to him, in order that we may co-operate.

The greater the distance thru which it is able to work, the less limited the applicability of the signal. One might think, then, that the most effective kind of signaling would be by reflex activity producing stimuli which affect the other animal's visual sense. But that is not necessarily so. Optical stimuli reach very far, but they have to go virtually in a straight line. Acoustical stimuli, on the other hand, go less far, but quite readily around the corners of intervening things. While light may reach my eyes thru billions of miles from a distant star, a friend standing only a hundred yards away in a dense forest may be invisible to me. He can not signal to me optically. But I can hear his voice, whose effect is not shaded from me by the intervening trees.

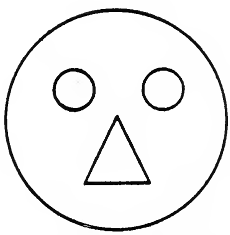
We find, therefore, that in the higher animals the signaling mechanism for the production of acoustical stimuli is as highly developed as that for the production of optical stimuli.

Let us mention a few examples of reflex signaling among human beings, in which optical stimuli are used, that is, stimuli acting on the visual sense of the Other-One. Such signals are the shaking of a fist, the showing of the teeth, the blushing of the face, when one gets ready to fight his enemy. If the Other-One responds to these signals by run-

ning away, so that one does not have to fight him at all, the signals have served their purpose well.

That animals as well as infants possess by inheritance reflexes of reacting to such signals, there is not doubt. They react to signals of form as well as of color, by reflex and also, of course, later by habit.

The present writer has repeatedly observed that children a few months old, with no experience whatsoever as to danger from animals, reacted definitely and strongly with shrinking, tension of the facial muscles, and crying when shown the face of a stuffed puppet representing a little pig of simple features like those of our figure. Since the reaction was the same in the case of different children and of somewhat different puppets, the conclusion is to be drawn that it was a reaction to the common features of these puppets, consisting in a circular head, two conspicuous circles within, the eyes, and a conspicuous triangle, the snout, as shown in the figure. Obviously, then, the sensory points of the child's eyes are by inheritance combined into a large number, perhaps thousands, of groups so that all the points stimulated by an appearance, in upright



A FORM SIGNAL CALLING FORTH NEGATIVE LOCALIZATION.

position, more or less like that of our figure, send their excitations to a single motor point or a single central point whence the flux is redistributed to cause the definite reactions mentioned. There are probably also many other

kinds of such groups, of other shapes, inherited by each individual of the human and animal race. In animals, too, similar definite reactions to the appearance of an object never experienced before have been reported by various observers.

That animals possess reflex responses to signals of light or color (independent of form) is also beyond doubt.

On the other hand, someone may find it difficult to understand that the color change of the first animal itself can be a reflex, that is, the result of a nervous current. For example, how can the signal of blushing of the face result from a nervous current? Do not think that this is less easily understood to be a reflex than are the other signals. Blushing means simply an increase of the blood quantity in the skin. And this is due to a relaxation of the ring-shaped muscle fibers in the walls of the blood vessels, which are now by expanding capable of yielding to the blood pressure and of carrying a larger quantity of blood.

For acoustical signaling most of the higher species of animals are equipped with a special sound producing apparatus. This is of great complexity in man. It may be regarded as consisting of two chief subdivisions, the blowing mechanism and the resonating mechanism. The former consists of the muscles varying the volume of the chest cavity, that is, (1) the diaphragm, stretched out below the chest, and (2) the muscles acting on the ribs. The resonating mechanism depends on the following six groups of muscles, each of these groups being capable of acting locally or in concert with the other five: (1) the muscles of the upper lip, (2) those of the lower lip, (3) those moving the lower jaw relatively to the upper jaw, (4) those of the soft palate, whose chief function consists in closing or opening to the air the nasal passage, (5) those of the tongue, and (6) those of the larynx, whose chief function consists

in bringing the two cushions, rather inadequately named the vocal "cords," of the larynx closer together or keeping them farther apart. These eight groups of muscles, together with the parts of the body on which they act, make up what we call our vocal organs or speech organs.

Leaving here the signaling reflexes we turn to an eighth fundamental form of animal behavior. Animals—with the exception, perhaps, of lower animals—sleep at certain times, especially during the night.

Sleep may interest the investigator from many points of view. One may ask, for example, what benefit the animal derives from sleeping. One may try to give a complete description of everything characteristic of the condition of sleep. One may ask whether this condition depends for its initiation and continuance on reflexes; and, if on other conditions, on what others. The most universally applicable, but not the only true, answer to the first question is, that the animal recuperates during sleep from fatigue, especially from fatigue of the nervous system.

As to the second question, a complete description of all the characteristics of sleep is out of the question in this book. But the chief characteristics of this condition of life must be mentioned. They are two. (1) A sleeping animal assumes a peculiar posture. (2) A sleeping animal does not respond to stimuli as readily in the customary manner as a waking animal. The first of these two is to some extent the cause of the second.

The peculiar posture of the Other-One—if we restrict ourselves to considering him—does not consist merely in the fact that he is lying and not standing. It consists also in the fact that his sense organs are more or less covered up. This is especially true for the eyes, but for other sense organs too. The ears are sometimes more or less covered, for example, by the neighborhood of his pillow or his own

arm. The nostrils are not always exposed to drafts of air as freely as ordinarily. The skin is exposed to stimulation less than ordinarily. The very absence of strong skeletal motions prevents stimulation which might come from the body itself.

But even when stimuli have access to the sense organs quite as under ordinary conditions, the Other-One does not respond to them readily in his customary ways. Speak to the Other-One while he is asleep, and he does not open his mouth for a reply. Of course, in saying this we take it for granted that you do not speak to him in an overloud voice. The explanation of the fact that we find him so unresponsive is obviously a condition of preoccupation, of absent-mindedness, in which he happens to be. We have discussed preoccupation in a former chapter and found that it results from having for a considerable time responded strongly to a certain class of stimuli by a certain class of reactions. But to what stimuli by what reactions in the present case? And what reactions therefore take the place of opening his mouth and speaking? The answer will presently be given.

Let us turn to the third question, which we can now easily answer. Are there any reflexes on which the initiation and continuance of sleeping depend? How are these reflexes described in their sensory and motor aspects?

They are, clearly, reflexes which have their adequate stimuli partly in daily recurring external conditions, such as darkness, (and also in seasonal conditions such as temperature, in the winter sleep of animals,) partly in internal conditions such as the physiological term "fatigue" refers to. The animal then retires, lies down, covers up, closes its eyes, etc. All these are muscular activities of a perfectly definite description. These muscular activities (keeping a certain posture is also a muscular activity), these re-

flex responses to the stimuli mentioned, then continue a considerable length of time.

No wonder, then, that the Other-One becomes "preoccupied." We ask him his name. He only closes his eyes tighter, covers himself up better. We let the alarm ring. He only presses his ears tighter into the pillows. Indeed, the Other-One being a possessor of habits, it could not altogether surprise us if his preöccupation should even lead to taking the alarm clock and throwing it out of the window. "It's nice to get up in the morning; but it's nicer to lie in bed."

Recapitulating, then, we can say that the phase of life called sleeping depends on the reflexes of sleeping. These reflexes bring about a posture generally unfavorable to stimulation. Their continued function—as any other continued nervous function—leads to preoccupation, so that the stimuli still capable of acting on the sense organs are as likely as, or even more likely than, to call forth their adequate responses, to bring about merely the continued reflex response of the sleeping posture.

Finally the stimuli characteristic of the sleeping reflexes cease. Darkness ceases. Fatigue in the body disappears. These reflexes function then more and more weakly, and gradually the preoccupation disappears. Other stimuli increase. It gets lighter. The noise of the day makes its appearance. People present themselves in the neighborhood of the Other-One and, intentionally or unintentionally, stimulate him more strongly and yet more strongly. Finally the Other-One reacts to one of these stimuli strongly and adequately:—he begins to wake up. He reacts to further stimuli of this ordinary class in the same manner, adequately:—he is fully awake. His adequate reaction is what we call his wakefulness.

Having now discussed eight fundamental forms of animal behavior—eight classes of reflexes or instinctive ac-

tivities—it occurs to us to ask whether right-handedness is a ninth or should somehow find a place among them. First, however, we must substitute the term "right-sidedness" for right-handedness, for the greater frequency of using the right side is not restricted to the Other-One's arm, but is equally obvious in the leg and in the head. But our definition of a reflex does not apply to right-sidedness. It is true, there is, in a sense, a particular "motor point" to which reference is made. But there is no such "sensory point" as the definition of a reflex requires.

We must say, therefore, that right-sidedness is not in itself a reflex, but that it is a peculiarity of other reflexes,—of those in which the motor point may, purely from the mechanical point of view, be located on either side of the Other-One's body. Among those reflexes in which right-sidedness may make its appearance, the most conspicuous class are the positive localizing reflexes, making up the third among our eight classes.

It is so well known that it need hardly be mentioned here that the left-sidedness of the minority of members of the human race corresponds in every respect to the right-sidedness of the majority, so far as the psychologist is interested in the matter. Outside of the human race right-sidedness seems to exist only, in some degree, in the anthropoid apes, and a little of it perhaps in the elephant.

A remarkable fact is that right-sided people show left-sidedness when they are small babies. Toward the middle of the first year (but by no means at this, the same definite, time in all individuals) or sooner or later the preference disappears, and both hands are now used with about equal frequency. During the second year (there being again great individual variations) the right hand begins to predominate. When habits of using a hand, as in eating at the table or in using a pencil, establish themselves, social influences

greatly strengthen the right-sidedness, for the teacher generally insists that the pupil use the right hand. But when the child learns to skate, and nobody tells him whether to slide a certain curve on one foot or on the other, he easily discovers himself, not only that he is right-sided rather than left-sided, but also that he is right-sided rather than merely right-handed. We shall have to say a little more about this in a later chapter, in discussing rhythm.

The change from left-sidedness to right-sidedness during babyhood seems to find its explanation in the following facts and conclusions. As to the time of the development of the right hemisphere of the brain in comparison with the left, we are entitled to a conclusion from analogy. The human brain with its complex functions is not fully developed until years after birth. The brain of larger animals of a longevity comparable to that of man, with its simpler, but no less important functions, is fully developed some months after birth. May not a similar rule govern the development of the left and the right hemispheres? The temporal part of the left hemisphere, with its highly complex speech functions, is not fully developed until years after birth—so much we know. By analogy we conclude that the symmetrically corresponding part of the right hemisphere, with its simpler, though no less important functions, develops to maturity at a much earlier period.

If this is so, activity of that hand which is governed by the right hemisphere, must become conspicuous at a much earlier period than activity of the other hand. Indeed, the left hand, whose muscles are closely connected with the temporal part of the right hemisphere, is the preferred member in the activities of the first few months after birth. Thus the fact that a normal human child is at first left-handed appears plain enough.

On the other hand, the question why the human adult is one-sided and right-sided is an entirely different one. The

answer to the first half of this question, why he is one-sided, we can leave entirely to the physiologists. The answer to the second half of the question, why he is right-sided, may be found in his need of securing protection, furnished by Nature thru heredity, for his most vital organ, his heart. The heart, previously covered, becomes exposed (in consequence of man's erect position) to the enemy fighting with weapons (in consequence of his erect position) rather than with his jaws. Right-sidedness gives some protection to the heart.

One might think, further, that a mistake has been made in not mentioning among the Other-One's reflexes or instinctive activities the important activity of walking. But we have hardly any right to regard that as instinctive. The reflexes of locomotion seem to be poorer in the species man than in many animals. Even creeping, in babies, seems to be an acquired habit rather than an instinctive activity. Walking is probably a compound habit, built up out of the habit of balancing on one (either) leg plus the positive localizing reflexes.

The complete ability of locomotion in the upright position involves two distinct abilities of muscular action: the ability to *rise from a lying to a standing position* and the ability to *balance on either leg.* The ability to rise is only imperfectly developed as long as holding on an object, a chair or the like, is necessary in order to rise. This imperfect ability usually precedes by several months the child's ability to rise to his feet from the floor without the aid of any supporting object. The ability to balance on (either) one leg is naturally preceded—as a rule—by the ability to *balance on both legs,* which, on the whole, is more easily acquired.

The governing reflex of the whole group in question seems to be that of *straightening the legs* in response to

pressure against the soles. A child about nine months old, or even considerably younger, may absolutely "refuse" to be held on anybody's arms in a sitting, flexible position. The reflex of straightening the legs causes a stiffening of the body. The mother then naturally places the child, no longer easily held in her arms when in this straight position, with his feet on her knees, or a table, or the floor. The child then stands, in a way, but retains this standing position only because he is kept from tumbling by his mother's arms. Soon the child learns to use his own hands, in the control of which he has by this time already acquired considerable skill, in order to keep from tumbling. He grasps whatever is in sight and reach and thus learns to keep in a standing position.

While the child is standing before an object, holding on with both hands, one of the hands accidentally loses its grasp, the body weight is thrown on the leg of the other side, and consequently that leg is straightened. The body as a whole, perhaps, is thus somewhat raised, and with it that leg which remained slightly bent. But now this leg, hanging and subject to the effect of gravity, straightens somewhat; and when the body regains its vertical position and the foot of this leg touches the ground, it straightens perfectly, owing to the reflex repeatedly mentioned. The weight of the body is thus thrown again—lightly—upon the other leg. A swinging movement of the body may thus result, from the left to the right, from the right to the left, and so forth. This is balancing sideways.

It is clear that this movement needs only a slight modification to become a regular walking movement. Children who are just beginning to walk, do indeed, usually, walk in this pendulum-like fashion, comparable to the walking of a sailor.

One finds here and there in psychological literature the assertion that the walking of a child is the result of an in-

stinct consisting in a tendency of the legs to swing fore and back in directions opposite to each other, and that these instinctive movements can be observed in a baby a few months old when held suspended. While such opposite fore and back swinging movements of the legs may sometimes be observed, it seems doubtful if they have much significance for the acquisition of the ability to walk, since one does not walk in suspension, but on a supporting surface. In any case, it is possible to derive the alternate movements of the legs in walking from the reflex of straightening each leg in response to pressure against the sole, without assuming any specific "instinct of walking."

We described how a child may learn to stand alone, balancing himself sideways. But in order to stand really alone he must also keep from losing his balance in the forward and backward directions. From falling forward he may be kept by the same reflex of straightening mentioned before. When the body begins to move forward, less weight is placed on the heels and more on the soles. Accordingly the foot straightens, the heel is raised above the ground and the body is kept from moving forward since the centre of gravity is now behind the point of support.

On the other hand, when the body begins to move backward, more and more weight is placed on the heels, the pressure on the soles vanishes, and the muscles which keep the legs straight relax. The knees then bend forward and thus a part of the weight of the body is thrown in front of the previous center of gravity, thus restoring the balance.

Just as the swinging of the body to the left and right, so these kinds of movement have great significance for walking. In the walking movements of a grown person the heel of one foot, when the body is already falling forward, rises with the straightening of the foot and raises, with

the whole body, the other foot perhaps quite sufficiently from the floor. This other foot, now free, by the mere force of gravity swings forward.

We have been trying to explain how a child learns to balance his body in the upright position, both sideways and front-back, without having to hold to an object. This balancing is virtually already walking. Before this accomplishment of standing free, the child usually begins to walk along by pieces of furniture, changing the hold of his hands as he walks on. What reflex is the basis of this locomotion? It seems that, in response to a visual stimulation, not only the hand but the foot, too, stretches toward the thing which impresses the eye. This is simply the positive localizing reflex.

The localizing reflex is the essential factor changing standing (balancing) into true walking. Imagine a child standing before a bench, holding on with both hands, and an object, say, a pencil, lying on the end of the bench to the right. The effect of the stimulation of the eye by the pencil is a stretching of the right arm and the right leg to the right. The body then falls to the right until the right foot again touches the ground. The body is now somewhat displaced to the right. The feet are farther apart than normally and are therefore, in consequence of special reflexes which we need not discuss, brought together to their normal position, but of course without any essential change of the body sideways. Now the whole stretching of the right hand and the right foot to the right is repeated until the hand grasps the object. Thus comes about walking along pieces of furniture or the walls of the room.

In the same way free walking results after the child has learned to balance himself without any support by his hands. While standing, in response to a stimulation of his eyes by an object he moves one leg slightly toward the ob-

ject, shifts his weight so that it rests on this leg and draws the other leg after, secures his balance, then moves again the first leg toward the object, and so on. One might call this form of locomotion walking on one leg only. In a week or two this one-sidedness gives place to the regular form of walking in which both legs take part equally. For many months thereafter, however, a child's walk remains clumsy because the legs are kept so far apart, owing to the anatomical fact that this opening of the legs sideways is the normal position until birth, which but gradually changes into that of the older child and adult, and also to the fact that balancing is easier in this position.

Usually a child learns to balance himself standing still without support by his hands, before he learns to move in the upright position. But there are exceptional cases where children, being held in the upright position, are suddenly attracted by an object, perhaps the mother's voice, and start off running successfully five or six steps until they have reached the object.

If walking is thus the outgrowth of standing, it is well to "encourage" free standing as much as possible after the baby has learned to stand while holding to things. What does it mean to "encourage" him? Let us reduce the process to its essential elements. (1) The child, when beginning to tumble, reflexly draws in his legs. (2) He has often tumbled, when standing and losing the hold of his hands. (3) Subsequently, by habit, he draws in his legs at once (in other words, he sits down) when standing and losing the hold of his hands. But he cannot practice balancing his body if he sits down. Therefore (4) we give his hands the same or similar sensory impressions as if they were supporting the body.

For example, we let the standing child grasp for support a small stick or pencil which we are holding, and then,

gradually, we cease to hold it. The child then balances and, although nothing supports him, receives almost the same stimuli in his hands and eyes as if he were still supported by the stick in his hands. The process of balancing suffers no sudden interference by a new stimulation (caused by the withdrawal of an object from his hands) and its reaction of sitting down. The "encouragement" which we give the child is therefore a purely negative event in the education of his nervous system: we keep an obstacle out of the way.

In psychological, and even more in sociological, discussions certain "human instincts" are often spoken of, which we do not care to enumerate among the fundamental forms of behavior of animals and of the Other-One for which Nature has made provision by heredity. We ought to give our reason why we do not regard them as special classes. Let us for this purpose give first the complete list of the eight forms of behavior which we have regarded as most interesting from our point of view.

1. Locomotion in a straight line in response to lack of food.
2. Turning the body axis sidewise in response to an obstacle.
3. Positive localization in its two forms.
4. Negative localization.
5. Grasping.
6. Adjustment of the sense organs.
7. Signaling.
8. Sleeping.

For example, "hunting" is sometimes mentioned as a human instinct. It seems that this form of behavior is a habit based essentially upon (1) and (2). "Tramping" is about the same. If one wants to distinguish between hunting and tramping, one may say that to the former (3) and

(5) also contribute strongly, for the hunter likes to follow the game (if he sees any) and to bring some home.

Further, "acquisition" or "hoarding" seems to be a habit based on (3) and (5). "Manipulation" or "construction" seems to be about the same habit. A child, let us say, picks up one of a number of wooden blocks lying about in his room. He receives the visual stimulation of a similar block, and since the nervous path is still favored by the reduction of the resistance due to the previous stimulation, reacts in the same way, walks towards it and puts on it his hand in which he still has the first block. Since now he cannot pick up the second block, he opens and raises his hand and, there, has before him a structure, one block upon another. Since this *double* block is a more striking stimulus than any of the single ones, it is quite natural that he returns to it, after having picked up one more of the blocks lying about. Is not all the so-called constructive activity simply a more or less complicated habit of the same kind as this very simple example? This habit of gathering and piling up must develop from the reflexes and habits which we have studied thus far, provided the child is surrounded by things which are sufficiently similar so that two or more of them together make a similar, but more intensive sensory impression than a single one; and what child does not live under such surroundings? It is hardly necessary, then, to assume a mysterious particular instinct of constructiveness. That the habit of taking to pieces, derived from the reflex of grasping, becomes united with this habit of putting together is plain enough, for taking apart brings about ever new opportunities for putting together. It is unfortunately true that taking to pieces is not inevitably followed by putting together. Nevertheless "destructiveness" is no more a human "instinct" than "constructiveness."

"Fear," running away, is a habit based on (4), negative localization. The peculiar attitude of a person in bodily

pain seems to belong to the same form of behavior. He shrinks away from the objects of pain. He curls up or writhes, bends and twists all his limbs.

"Attention" is sometimes called an instinct. What is referred to is obviously habits based chiefly on (6), to some extent also on (3).

"Sociality" is sometimes called an instinct. It refers to those habits which are based on (7). The response to the signal brings about social relations.

The so-called instinct of "idleness" is based on (8). A person who acts habitually "sleepy" when we expect him to expose his sense organs to all or to certain stimuli, is an idler.

In connection with "instincts" it has become the custom among psychologists to speak of "emotions." From the social point of view emotions are most curious phenomena. But if we analyse them psychologically, we find that they are nothing but "wasted" reflexes. For example, if a person shows most or virtually all the symptoms of "sleep," that is, reacts with the sleeping reflexes above discussed, but during the day and under conditions where such reaction serves no purpose, naive observers may be excused for saying that he experiences sorrow and anguish and thinking that his very soul has been stirred up. But to the scientific observer this sorrow and anguish is merely a wasted sleeping reflex. The situation calling forth the reflex action is one of disappointment. And the reflex action means retiring to a state of more or less prolonged inactivity.

We can at once derive the symptoms and comprehend the biological value of his reaction if we recall that in animal life and in the life of primitive man the most ordinary kind of disappointment consists in the want of food. Imagine a winter month: every article which might serve as food covered by snow and impossible to find, for weeks or longer,

until the weather changes. An animal which, under these circumstances, would continue to run about for food, would soon fall dead from exhaustion. However adverse the situation, the body can survive living on the substances stored away in its own tissues, if it only consumes this limited supply economically. For this the first requirement is that all muscular activity be reduced to a minimum.

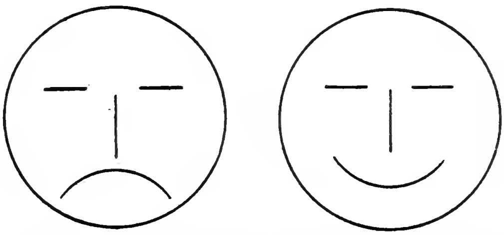
Thus we understand why the nervous system, in a disappointing situation, tends to leave the skeletal muscles in a state of relaxation. A person in great sorrow is so far from being master of his skeletal muscles that he drops as if he were completely paralyzed, like Romeo in Friar Laurence's cell:

> "Wert thou as young as I, Juliet thy love,
> An hour but married, Tybalt murdered,
> Doting like me, and like me banished,
> Then mightst thou speak, then mightst thou tear thy hair,
> And *fall upon the ground,* as I do now,
> Taking the measure of an unmade grave."

A disappointed person looks like the face on the left side of our double diagram of facial expressions. The relaxation of the facial muscles causes the angles of the mouth to be pulled down by the weight of the lower jaw. But why should such a face look pale?

Recall the animal just spoken of, disappointed in its food supply. If it does not exercise its muscles, little or no heat is produced, for the skeletal muscles are, physiologically, the very furnaces of the body. If little heat is produced, the loss of heat must be safeguarded against. Thus the biological value of the contraction of the muscles in the walls of the blood vessels becomes evident. The contraction of the vessels prevents the blood from circulating much in the periphery of the body where cooling mainly takes place.

The cooling by the conduction of heat through the tissues covering the body is little to be feared as long as the warm blood is kept in the inner parts of the body and prevented from circulating through the periphery. The actual cooling of the skin, exciting the sensory points of the skin, causes the reflex and habitual response of the animal's seek-



FACIAL EXPRESSION IN SORROW AND IN JOY OR ANGER.

ing shelter, again reducing the loss of heat, of physiological energy. Thus contraction of the blood vessels of the skin keeps the animal alive until a change of the external conditions enables it to resume its ordinary manner of life.

The winter sleep of animals might, in a sense, be called a prolonged emotion of sorrow. But in this case the sleeping reflexes are not wasted. In the case of Romeo they are wasted.

Many psychologists attempt to place each class of "emotions" parallel with one particular class of "instincts." The sleeping reflexes would then become the basis both of the habit or "instinct" of acting sleepy or lazy and, when wasted, of the "emotion" of sorrow.

The reflexes (3) and (5), which result in the habits or so-called instincts of acquisition, hoarding, manipulation, might then well be said to be, when wasted, the bases of the emotions of joy and of anger. That the angry person manipulates things too much and very wastefully, is sufficiently known. And the joyful person "localizes," picks out, not this or that thing, but the whole world, in order

to "grasp," to embrace it,—but ordinarily to no good purpose. The strong (primitive) activity of grasping, or trying to grasp, with the jaws (having teeth for that end) gives the face the feature shown on the right side of our double diagram of facial expressions. We see this "grinning" both in what we call joy and what we call anger.

The horse, standing on a railway track, which runs away from an approaching train, is not said to display an emotion. It demonstrates its negative localizing reflexes (4). But if it wastes these reflexes by running away from a newspaper flying in the wind, we speak of it as having an emotion.

Sometimes we speak of "play" rather than of emotions, when an animal exercises its reflexes to no directly useful end. We speak of play especially in the case of young animals and of children, where wasted reflexes are naturally more frequently seen than in the case of adults. Even when directly wasted, the exercise of the reflexes may be indirectly helpful. It has often been pointed out by psychologists—and quite rightly, it seems—that thru play the young acquire useful habits before dire necessity demands their acquisition.

When the Other-One's play becomes connected with Art, or when he plays with a work of Art or even with a product of Nature like a beautiful landscape chiefly by adjusting his sense organs to it, we say that he has an "esthetic" emotion. He calls those things beautiful which he discovers to be particularly suitable for this play of adjusting his sense organs. And by Art he means the production of such things. As a matter of course with advancing age, experience and training the esthetic emotions become infinitely varied by becoming interwoven with the Other-One's innumerable habits.

CHAPTER IX

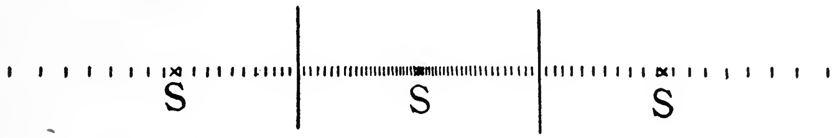
Space Perception on the Skin: A Species of Condensation of the Nervous Functioning.

We mean by a spatial perception any muscular reaction which can be regarded as based on the positive localizing reflexes in such a manner that for two—or any larger number of—localizing reactions which remain unexecuted an entirely different muscular reaction, serving any end whatsoever, is substituted.

The equipment which Nature has given the Other-One in order to make localizing movements possible has already been discussed and is very simple. It consists of a large number of nervous conductors, reflex paths, each starting at a particular sensory point and ending in that set of muscle fibers (schematically speaking, that motor point) the contraction of which will bring a movable part of the body, most commonly the tip of the index finger of the right hand, into the neighborhood of the sensory point in question. We say advisedly "neighborhood." The Other-One's muscular apparatus works, of course, with a certain inaccuracy. This would show itself clearly if the Other-One would localize, "try to touch," the same sensory point a large number of times, perhaps a hundred times, and leave a mark on it with an inked point of the finger tip after the performance of each localizing movement.

Suppose the sensory point to be touched is selected on the upper arm about midway between the shoulder and the elbow. Suppose we consider the distribution of the marks just mentioned only in the direction lengthwise on the arm, and disregard completely whether the marks distribute themselves crosswise in any manner or not. In the distribu-

tion lengthwise we should mark, following the general scientific custom, the two points, one lying toward the shoulder, the other toward the elbow from the sensory point, between which we should find one half of the marks of all the localizing movements, that is, fifty of the hundred. Imagine, in order to have something definite to speak of, that the distance between these two points happens to be just an inch as in our figure between the vertical



MARKS OF THE LOCALIZING REFLEX.

lines. Now imagine, further, that you are assistant to the Creator of the world and that the task has been assigned to you of placing in the skin of the arm, from shoulder to elbow, a sufficient number of sensory points. How close together would you place them? (Now suppose that your standard of efficiency happens to be "half and half" in the sense which will be apparent at once.) You would obviously not waste them by putting them closer together than an inch.

Due to the inaccuracy of the execution of the movement, one half of the marks, we supposed, fell farther than half an inch above or below the sensory point. If you place the sensory points one inch apart, half of the marks will fall closer to the sensory point touched than the sensory points untouched, whose localization by a movement is not demanded by any present need. If you place the sensory points closer together, fewer and fewer than one half can be said to have fallen closer to the sensory point touched than to the sensory points untouched.

It would obviously be a waste of biological building material to possess sensory points which, altho untouched, collect in their neighborhood more than one half (or more than

any other definite fraction which represents your standard of biological efficiency in your creation) of the marks which were intended for a different point as a target, this target receiving then in its neighborhood only a certain minority of the marks.

We have here one of the reasons why creative Nature should place a rather limited number of sensory points in the skin, why Nature should establish what is technically called a threshold of sensibility, and a rather large threshold.

Of course, we do not assert that Nature may not, for this or that other reason, distribute the sensory points less closely or more closely together than corresponds to the muscular accuracy. It may, for example, be quite sufficient for an animal's need of protection, if the sensory points are farther apart, because the animal's paw or the human hand, in making a localizing movement, is capable of touching—covering—a broad area.

By the way, in this discussion we have intentionally not concerned ourselves with the fact that what we schematically call a sensory point is not a geometrical point, but an area of some size served by numerous branches of the same neuron fiber in question. Taking up the study of these details of the finer anatomy of the skin would be likely to carry our interest from psychology into physiology.

An experiment will make the further discussion more concrete. We ask the Other-One to close his eyes. Then we touch him, after a "ready" signal, lightly, but with sufficient firmness and long enough, one to two seconds, with two compass points. He answers our question, whether we touched him with one point or with two. We repeat the experiment with a different distance. If we choose to make the distance increase, or decrease, with regularity, we must touch him now and then with only one point in

order to test his sincerity. If he answers "two" in such a case, we tell him that we have no use for him as a subject of experimentation.

Finally we make an array of our data, with distances regularly changing and the Other-One's answer to each distance added. We then notice at one end of the array only judgments of "one," at the other end only judgments of "two," and in the middle both judgments mixed. The distance standing in the center of this "mixed" region we call the threshold.

The experiment is made lengthwise on the arm, and it is also, separately, made crosswise on the arm. The most interesting result is that the threshold lengthwise is greater than the threshold crosswise. One reason for this will be pointed out later.

Let us now consider the relation between the experiment on discrimination as just described and the localizing reflex. At the first glance it may seem that (1) localizing a point stimulated and (2) calling out either "one" or "two" according as two nearer or farther points have been stimulated, are two forms of human behavior which have nothing in common. But that is not so. They are very closely related functions. The latter form of behavior is a modification of the former, a habit based on the localizing reflex.

It will make it much easier for us to understand this, if we first recall what reaction is most commonly, in the Other-One's life, substituted for any single one of his reflex actions. The most common substitution is that of "naming." A human adult whose shoulder is irritated, in innumerable instances, for example in the presence of his physician, pronounces the word "shoulder" instead of moving his finger to the shoulder. If his elbow is stimulated, he pronounces the word "elbow." This is one of the most common habits in human life, reacting by a word

instead of reacting by a directly useful muscular activity. The naming reaction is indirectly useful, chiefly thru its social consequences, since the word in turn is likely to bring about in another individual, or in many other individuals, that directly useful reaction which the person stimulated did not perform. When the Other-One says "shoulder," his physician will probably put his finger on the Other-One's shoulder.

Now imagine, first, that the following happens. The Other-One is touched on his shoulder; but peculiar neuro-muscular complications delay the reaction. His shoulder is touched again; and now both of these stimuli are responded to by a single reaction, perhaps that of pronouncing the word "same." Same in the sense that the muscular reactions were the same. No one will deny that this is possible, that an animal body, instead of reacting separately to each of two successive stimuli, reacts to both of them in a new way with a single movement, of course not in this case reflexly, but in consequence of habit formation. Secondly, imagine that the Other-One's shoulder is touched first; but special conditions again delay the reaction. His elbow is now touched; and both these stimuli are then responded to by a single reaction, perhaps that of pronouncing the word "different." Different in the sense that the muscular reactions were different, as they naturally must have been.

It is clear that the pronounciation of such a word as "same" or "one" in the former case and of such a word as "different" or "two" in the latter case is nothing but a peculiar kind of habit, consisting in a single reaction occurring as the effect of two (in our case successive, but not necessarily always successive) stimuli, this single reaction taking the place of the two localizing reflex reactions which originally belonged to, were casually connected with, the two stimuli.

What we have just done, has been nothing but a logical analysis and clear statement of what is meant by that form of behavior which we customarily call "discrimination" of two points. Let us now return to the result of our experiment concerning the comparative threshold lengthwise and crosswise on the arm. We found that the threshold was considerably larger lengthwise than crosswise. Why has Nature placed the sensory points closer together in the direction crosswise, thus increasing in this direction the number of distinct reflex actions possible and also, then, the number of substituted word reactions "different" or "two"? The reference to a limit of muscular accuracy in localizing the spot obviously is no answer here. We can give an answer to this question which is applicable, not only to the arm, but to the whole body surface.

The sensory points are the closer, the greater the curvature of the surface region in question, the farther apart, the less the curvature. It goes without saying that the curvature crosswise on the arm is much greater than lengthwise. We then have before us the same question in different terms. Why does Nature increase the number of sensory points whenever the curvature increases?

This question can be answered when we remember that the purpose of the existence of sensory points on the body surface is a localizing reaction, but that the end of the localizing limb is not a sharp point. A finger tip, and more so a flat hand, is capable of covering a considerable area, say, of the arm, in the localizing reaction. But this covered area has a considerable extent only lengthwise, that is, where the curvature is small. Even a great inaccuracy of the localization lengthwise will still result in the stimulated part being covered by the flat hand, as when we swat a mosquito sitting on our arm. Not so crosswise. If the mosquito moves only half an inch or so in the direction

crosswise, the striking hand will not kill it. To kill the mosquito in the changed position, a very different combination of contracting muscles is required, and the excitation must be carried over distinctly different conductors. It is immediately clear, then, that an animal needs to have its sensory points on the body surface much closer together as the curvature increases.

It may be wise to add to the last statement, that this does not imply that the number of sensory points should be expected to be strictly proportional to the curvature as defined in mathematical terms. An assertion of strict proportionality would lead to the absurd consequence of the sensory points being an infinite distance apart where the body surface has no curvature, is flat, not to speak of the still more absurd consequence of the distance between the sensory points being negative where the surface is concave, as in the palm of the hand.

For reasons which are apparent in a discussion of space perception, it is advisable to raise the question as to how many dimensions are involved in the description of the mutual relations of those stimuli which call forth this form of behavior, the localizing reaction on the skin. The answer to this question is that the stimuli may all be described as belonging to a two-dimensional space. The objection that the skin, in which the stimulated sensory points are located, obviously fills the three dimensions of common sense space, is not a real objection.

Of course, nobody making this objection would mean by it that the skin has thickness and in this respect has three dimensions. The stimuli in question are not applied to a varying depth in the skin. The objection could have a meaning only in the sense that the skin surrounding the Other-One's body is not flat. It could not surround the body if it were flat. But two-dimensionality and flatness

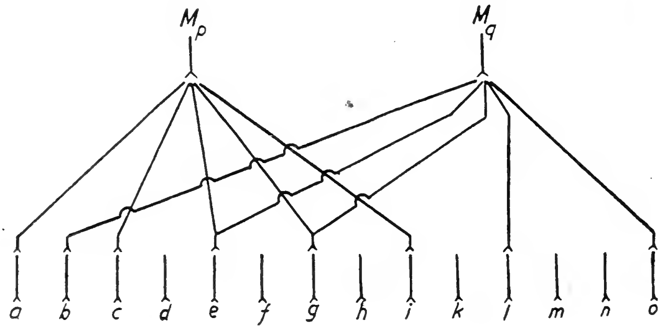
are not the same, mathematically. We can make this clear even in purely biological terms, leaving all abstract mathematics aside. Imagine you could skin the Other-One in such a way that all the nervous conductors having endings in the skin would remain intact. Think of the nerve fibers as being stretchable, like rubber threads. Imagine that you had spread out his skin on the flat floor like a fur rug, without in the least interfering with any of the normal nervous connections between the points of his skin and the Other-One's muscles. It then becomes clear at once that the skin is functionally a two-dimensional structure. You could distribute the stimuli over the (now flat) skin lying on the floor in exactly the same two-dimensional relations as before (when the skin surrounded the body) and call forth in the Other-One exactly the same muscular responses. That the skin is curved over the body, obviously does not change its functional two-dimensionality.

We therefore say that the space perception on the skin is a perception of only two-dimensional space. But the only example we have hitherto given of this space perception has been the rather simple case of the discrimination of two points. Let us now turn to cases of space perception which are a little more complex, and see whether they too can be reduced to habits based on the localizing reflex.

Imagine the following case. The Other-One, in the dark, is trying to find a pen point which he knows is lying among other things on the table in his room. He puts his hands on the table. A number of sensory points forming an oval spot on the skin are stimulated by contact on his right hand. A number of sensory points along one line are stimulated on his left hand. He ought to pick up that thing which is lying under the latter. It is the pen point wanted. What is lying under the right hand is a medal. Of course, instead of using both hands, the Other-

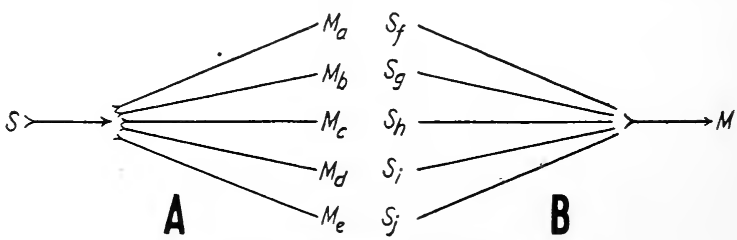
One may put the same hand, first on the one thing, then on the other.

We are dealing here with the problem of the perception of spatial form reduced to simple terms. We might give names to the sensory points and call them for the pen point a-c-e-g-i (they are, of course, in reality much more nu-



SPACE PERCEPTION AS A NERVOUS FUNCTION.

merous than five), for the medal b-e-g-l-o. We notice that some, but not all, which are found in the one group, are also found in the other. We may imagine that the reaction, say, the bending or the stretching of the arm in all its joints, is anatomically very simple, that it involves the contraction of only a single muscle, the passing out of the nervous current at a single motor point. The nervous func-



SPACE PERCEPTION THE REVERSE OF MOTOR CONCERTEDNESS.

tion is then exactly the opposite of what we have called on the motor side concerted action, which we have discussed in a previous chapter. Motor concertedness is characterized

by an expansion of nervous function which one might represent by a fan-shaped diagram like that on the left side of our figure, at A. In space perception, on the other hand, we let the "soldiers," so to speak, who started out marching in open formation, arrive at their aim, M, in close formation, as at B in the figure. Here they arrive as a single unit of motor function, in the other case, A, as five units of motor function. We have already called this, in contradistinction to concertedness, condensation of the nervous functioning, or "motor condensation" if we call concertedness "sensory condensation."

Space perception then is a species of condensation of nervous functioning. Discrimination of two points on the skin is the very simplest example of space perception. An example of a more complex discrimination has just been given. Another example would be that of reacting differently to three stimuli applied to points forming a straight line and applied to three points marking a triangle. Or distinguishing—of course again by different muscular reactions, most usually the names pronounced—one kind of triangle from another kind. Or one triangle from another one which is merely larger.

It is clear that in thus distinguishing different sizes and different forms, some of the group of sensory points calling for the one reaction may be identical with some of the sensory points of the group calling for the other reaction. In our figure "space perception as a nervous function" this is expressed by the fact that the points e and g are found in both the groups a-c-e-g-i and b-e-g-l-o.

How such habits of space perception may be formed on the basis of the localizing reflexes, we have illustrated by the example of the discrimination of two points on the skin. But we must not think that all space perception, all such condensation of the nervous functioning, results mere-

ly from habit formation. There is very definite evidence, especially in the reflex reactions to reflex "signaling," that certain kinds of space perception are inherited. But since the plainest examples are found in visual space perception, we shall give them on a later occasion in the next chapter rather than here where we are discussing cutaneous space perception.

Space perception is an especially fertile field for the culture and observation of so-called illusions. Any wasted reflex or habit may be called an illusion (just as it may be called an emotion). The crowing of a rooster (a signaling reflex) may be called an illusion of the rooster when there is nobody to hear the sound. Striking a table with a fist when nobody is present to be caused to run away or shrink from the person who does it, may be called an illusion. Swallowing a pill, when it is only a sugar-coated pea, may be called an illusion. In the last mentioned case, the action is applied to something, but is nevertheless wasted because it is misapplied.

It is not difficult to see why the probability of an action being misapplied is especially great in nervous functions which are of the nature of a condensation of the totality of the nervous currents. If the currents coming from b, e, g, 1, and o all concentrate toward the motor point M_q in our figure and four of them (one of the five happening to be absent, we speak of the other four) concentrate ordinarily toward some different motor point M_x, it is only to be expected that the mere weakening or total failure of that one of the five currents should once in a while be insufficient to keep the other four from concentrating just the same toward the motor point M_q. The following is a concrete example.

Perhaps the most famous illusion in cutaneous space perception is that which goes under the name of "Aristotle's

illusion," which indicates how long it has been known. Place the Other-One's hand palm upwards on the table and cross his ring finger over the middle finger. The tip of the ring finger then lies next to the index finger and the tip of the middle finger next to the little finger. Of course, before doing any of these things you have already blindfolded him. Now touch gently the tips of the crossed fingers with a single object, for example a bean or a round pencil. The Other-One will then probably tell you that he was touched by two things.

The explanation is simple enough. When the tip of the ring finger is stimulated on the side which ordinarily lies next to the little finger and also the tip of the middle finger is stimulated on the side which lies ordinarily next to the index finger, the Other-One ordinarily must execute two separate localizing-grasping movements before he has "picked" all the stimulating objects. He has learned to substitute the word "two" if he substitutes a naming reaction for these reflex movements of "picking." It is true, the nervous function includes in such a case also the excitation of the kinesthetic sense organs in the muscles which hold the fingers parallel.

Now, in the experiment in which the subject is blindfolded, this kinesthetic excitation is not the proper one. The proper one is not there (there is something else in its stead). But, as we already said, the absence of one nervous current among several in the case of nervous condensation does not always keep the others from concentrating in the same motor point. If they do concentrate in the same motor point (and as a matter of fact and ancient experience, far back to Aristotle, they frequently do), the Other-One tells us "two." Of course, his reaction is not always and by absolute necessity saying "two;" but frequently, perhaps in a majority of the cases, he does say "two."

It is an illusion because the response is misapplied. The Other-One will quickly admit that the response "two" was misapplied, was "wasted," when we uncover his eyes. We ask him to pick up and give us the two beans. But after having picked up one, he finds no second bean to pick up.

CHAPTER X

Nature Enables the Other-One to Perceive Space at a Distance.

The eye must be regarded as a group of sensory points of the skin whose sensitivity has been changed so that they can be stimulated, no longer by pressure very easily, but by certain ether waves, by light, even when this light is only very weak. In our chapter on reflexes we referred to the fact that the sensory points of the Other-One's retina have been equipped by Nature with definite reflexes. When the lower region of his retina is stimulated, his arm moves up; and so forth. We called these reflexes positive localization in the outward direction. From them is derived, by condensation of the nervous functioning, space perception at a distance, just as space perception on the skin is derived from the localizing reflexes of the skin.

Let us mention a concrete example from the Other-One's life. One evening, long after sunset, we find him walking in the wilderness trying to discover a resting place for the night, a human habitation. On his right there is a hill; on his left another. Over the latter appears a bright spot which is round. Over the former there is a bright spot which is rectangular. He ought to turn to the right where he will approach an illuminated window, Over the hill to the left there is something he could never hope to approach, the moon.

Obviously, the case is in all essentials the same as that, discussed in the last chapter, of discriminating by distinct reactions a pen and a medal, both touching the skin. In

stead of the localizing reflexes serving the skin, we find here those serving the retina. And just as there, so we find here a substituted motor function. For several, a definite group of, localizing reflexes a single habit is substituted, the habit of approaching the illuminated rectangle, and of leaving behind one's back the luminous disk. With the localizing reflexes of the retina we are already acquainted. In discussing the localizing reflexes we spoke of the fact that the eye ball functions like a pin hole camera (it actually is a lens camera) and that the establishment of reflex paths here is as simple a problem for the architect of the nervous system as it is in localization on the skin.

In the preceding chapter we called attention to the fact that those condensations of the nervous functioning which we call space perceptions are not entirely the result of habit formation, that certain space perceptions are provided by the inheritance of nerve centers higher than those which serve the simple localizing reflexes. We promised to give an example of inherited visual space perception. We can now give it. This example has already been mentioned in a previous chapter, but there for a different purpose. We discussed the fact that animals as well as infants possess by inheritance reflexes of reacting to signals of form which are given out by other animals (or animal-like things, as we shall see). We illustrated the discussion with a simple figure being a sketch of the main features of a stuffed puppet.

These features are a circular or oval border line and within it a triangle (a "snout") below, and two smaller circles ("eyes") above. The fact that young and entirely inexperienced babies react to such a form with the negative localizing reflexes, in ordinary life called "fear," shows

beyond doubt that they possess this condensation of nervous functioning, "spatial perception." Instead of several (a large possible number of) positive localizing reflex actions, one substitute action occurs, which happens to be in this instance a negative localizing reflex.

How the habit formation and the functioning of established habits in visual space perception are influenced by the geometrical relations between the sensory points on the retina, becomes evident in a study of the geometric-optical illusions. We shall presently give a number of especially striking and typical examples of such illusions. Let us remember that such illusions are "wasted" reactions. And let us keep in mind in the following discussions that until the contrary is especially stated, we shall concern ourselves with the two-dimensional visual space perceptions, that is, those where the location of the sources of the emanating stimuli is completely described by reference to the so-called "field of vision." For the present we leave "depth" out of consideration.

The geometric-optical illusions furnish striking illustrations of the fact that space perception is a species of condensation of the nervous function. By various factors we can guide the special direction which the condensation takes in the nervous system. Thus we can vary the reaction in the most astonishing, often seemingly contradictory, illogical, wasteful manner, without essentially changing the form of the object, that is, without essentially changing the particular sensory points stimulated.

Let us ask the Other-One which two of the upper three lines, a, b, and c, in our figure are the continuations of the lower two lines, d and e. Maybe the Other-One will refuse to answer our question and rather say that none are continuations, that d and e pass thru the vacant spaces be-

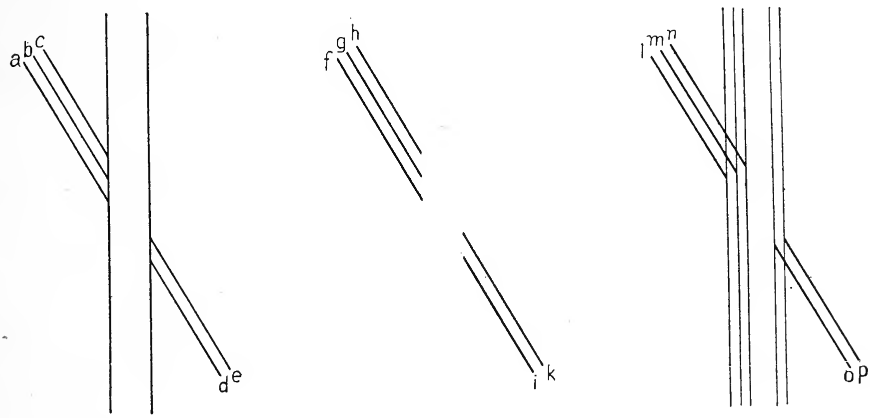
tween a, b, and c, as they actually do. But if he answers it as it is put, he will certainly not say b and c. He will say a and b. Why?—Some psychologists have held the vertical lines responsible for this choice. They have said that the illusion is due to the overestimation of the acute angles formed by the lines of the figure.

It is perfectly true that there is a tendency to overestimate acute angles and underestimate obtuse angles. And the reason for it is clear. Look in one of the corners of your room at the angles you see there. They are three obtuse angles. But you know that in reality they are three right angles. Right angles are exceedingly common in architecture and furniture. They are common enough also in trees, since these generally stand vertical on the ground. A log or trunk of a fallen tree lying at the foot of a living one and forming a right angle is nothing rare. So everybody is very familiar with the fact that angles which are apparently acute are in reality often larger than they seem. These experiences may have some influence on the estimated size of acute, and in the opposite manner of obtuse, angles.

But that this influence must be small and cannot be the deciding factor in the Other-One's illusion just mentioned, becomes clear when we make him look at the middle of our figure. Which two of the upper lines, f, g, and h, are the continuations of the lower two lines, i and k? The illusion is just as strong altho there are no vertical lines nor angles. And let no one introduce "imaginary," merely suggested, lines as explaining the illusion.

Imagination, when we speak of the Other-One, is only a synonym for his "habits" of handling the things in question, for example, of drawing lines in a thing or design which is given to him without them. Now, that he may have and

use habits of drawing lines, we need not deny. And that these habits influence the acquisition or the function of other habits such as answering our question addressed to



NERVOUS CONDENSATION DEPENDING ON DISTANCE OF POINTS STIMULATED.

him, we need not deny. But, if we can find a more directly acting cause for his manner of answering our question, this direct cause will interest us much more than those indirect, contributing, causes.

We need not introduce any new principle of explanation. We merely remember what we have asserted about space perception in general. Two lines are called by the Other-One a single line under certain conditions, just as two points are called one point under certain conditions. Two points and two lines are the more easily regarded as one, that is, as each other's continuations, the more the nervous currents coming from the points stimulated—other conditions being equal—unite to act as one current. We can also express this thus: the more completely the total nervous function is condensed into one motor point.

Where the distance between two stimulated points is far less than the threshold, the fulfilment of the condition just mentioned is obvious. It is then due solely to our natural

equipment. Where the distance between two stimulated points is considerably greater than the threshold and nevertheless the response demonstrates that there has been condensation of the nervous functioning, the condensation, on the other hand, is a habit. Such a habit must be formed quite naturally whenever the successful localizing reflex "number 1" makes the success of the localizing reflex "number 2" impossible,—for example, if, after "grasping" one of the lines or sticks (whatever they may actually be), the Other-One finds no second line or stick any more to grasp.

This habit, once formed, altho it is a habit of reacting to stimulations farther apart than the threshold, cannot in its functioning be entirely independent of the distance being very large or only moderately (tho always above the threshold) large. Surely, when the distance of the points stimulated is larger, the condensation must be less liable to occur; and when the distance is less large, the condensation must be more likely to occur. Where instead of points we have lines, the distance just referred to as being greater or less must be the distance between the end points marking the break, the discontinuity. Other conditions (which might also be determinants of the condensation) being equal, we must accept the rule that, the less the distance, the greater the probability of condensation of the nervous functioning. Or, is it not true that in our actual and practical experience, whenever the middle part of what seems a crooked stick is invisible, the stick is the more frequently found to be a single crooked stick, and the less frequently found to be two separate straight pieces, the closer together lie the ends of the two visible straight pieces?

This rule applied to our illusion diagram explains the Other-One's—at first surprising—answer quite readily. It is true that the "nervous current i" (one will understand

what is meant by this abbreviated phrase) may, on abstract logical grounds, no more easily unite with "the current f" and pass with it into a unitary motor outlet than with the "nervous current g." This is certainly true so far as the mere direction and position of the stimulating lines are concerned. The lines are parallel and a definite distance apart. Why not call them two?—But from the nearest end of the line i to the nearest end of the line g is a much greater distance than to the nearest end of the line f.

Thus it goes almost without saying that condensation occurs much more easily with reference to the nearer neighbors i and f; and that the Other-One will more frequently call i and f together "one straight line with an accidental break in the middle" than i and g together.

For further demonstration of the much greater importance of closeness than of any other factor contributing toward condensation of the nervous functioning let us look at the right side of the last figure. Which two of the three upper lines, l, m, and n, are the continuations of the lower lines, o and p? There is no preference here, no illusion. It makes no difference whether we draw vertical lines thru the endpoints or not. Even when we have drawn them and the angles are quite clearly seen, so that the Other-One is in no manner kept from overestimating the acute ones, he does not "waste" his reaction. The distances are here the same between the end point of o and the end points of l and m; the same between the end point of p and the end points of m and n. It is therefore not to be expected that either the pair l and m should be preferred to the pair m and n or the latter pair to the former, when the question is raised how the lines o and p are to be continued upwards. That is, there is no cause for any illusion.

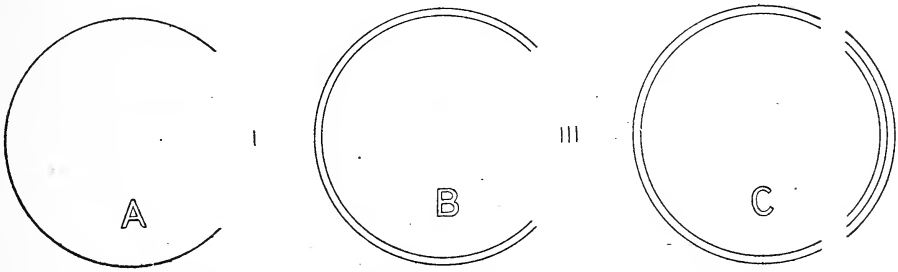
If on the contrary the angles were powerful factors, the Other-One should have an illusion in spite of the equality of the breaks. Since he scarcely has any illusion, it is clear that his habitual overestimation of acute angles is not the chief cause of this illusion here. The cause of the illusion is much more fundamental, much more elementary. As we have seen, it consists in the simple fact that sensory points on the retina (and the same rule holds for the skin) which are closer together are more likely to be functionally joined by what we have called condensation than sensory points which are farther apart.

Another important fact must be mentioned here. Psychologists have often relied too much on mere logic. If for two reactions (localizing reflexes) a single new reaction (saying "one") is "substituted," then the single reactions are "excluded." So logic rules. But the facts are otherwise.

Most striking is this event in the discrimination of two points; and there is no essential difference between discrimination on the skin and on the retina in this respect. The Other-One sometimes says: "I call it one and am a little inclined to call it also two." (Of course, this happens only in the neighborhood of or somewhat below the threshold, unless the Other-One is a pure guesser and insincere subject.) It is impossible to interpret away the lack of logic of the statement. However, what has formal logic to do with the case? Near the threshold the condensation is pronounced enough to bring forth the substituted reaction "one" and yet not enough pronounced so that currents of considerable strength will not be able to get still to the reflex motor points of localizing each point separately. Why should this not be so? It is perfectly natural.

In the following figure of incomplete circles there is a further illustration of the principle of nervous "condensa-

tion depending on distances." At A the little vertical dash (small arc) on the right does not seem to belong to the circle. It seems to lie too far to the right. With reference to B we ask the Other-One the question: "Which two of the three vertical dashes (small arcs) on the right



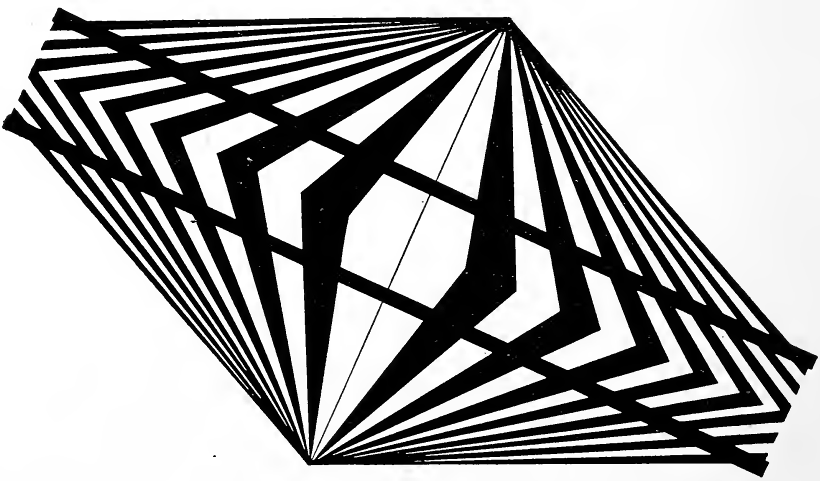
ANOTHER EXAMPLE DEMONSTRATING NERVOUS CONDENSATION.

belong to the two circles?"—He tells us: "The two left ones." Why does he not tell us "The two right ones?" The circles have intermediate positions relative to the locations of the circular continuations of the dashes. Therefore, logically one of these answers should be as probable as the other. Actually the second answer never occurs. The greater nearness between the end points at the break determines the answer. The nervous currents of the two right dashes do not together with the nervous currents of the circles lead to the single motor response "one ring." The distance of the end points is (relatively) too great.

At C the two large arcs are, in a geometrical sense, intermediate between the three small arcs. No two of the arcs are parts of a single one of the concentric circles, of which there are actually five. But if you ask the Other-One which two of the three arcs on the right he would prefer to call the continuations of the two arcs on the left, he will choose the outer ones. He will not, as in the preceding case, choose the inner ones. It is perfectly clear, why. The end points of the two outer arcs on the right

in this case are closer to the end points of the left arcs; the end points of the two inner arcs on the right are farther from the end points of the left arcs. So the former nervous currents enter more readily into a condensed function; the latter currents tend more to remain an expanded nervous function.

There are, however, geometric-optical illusions (that is, we remember, "wasted" space perceptions) in which appears clearly the overestimation of acute (and underestimation of obtuse) angles. This tendency to regard angles as more approaching in size a right angle than they actually do, is illustrated very conspicuously as the main factor

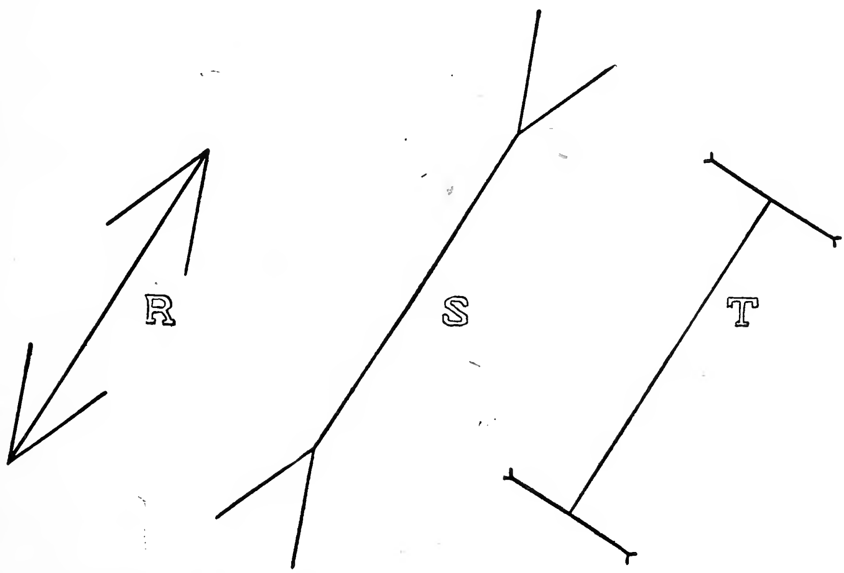


THE WRONG ESTIMATION OF ANGLES (PERSPECTIVE) SEEMS TO CAUSE THE TROUBLE.

of the illusion in the figure where two parallel slanting lines are the stimulus to which the Other-One responds by saying that they are curves tending to surround the upper and the lower centers of radiation.

On the other hand, the principle of "nervous condensation depending on distances" is again clearly brought out by the three slanting lines, which, because of the nature of

the lines which mark their endings, the Other-One most probably will pronounce as of unequal length. It is a story like that told of the founder of Rome, who bought as a site for his city just enough land to permit him to spread out a cowhide. But he was careful to cut the hide into a very long and narrow strap before he spread it on the ground. In R the stimulated sensory points which mark the ends of the line spread out forming, so to speak, two triangles. The vertices of the triangles lose their significance in comparison with the inclosed areas. The nervous currents of these endpoints are quite likely, therefore, to fail to play in the condensation of the nervous function that role of relative importance which they ought to play in comparison with the triangle areas. Since the triangles



DIFFERENT FORMS OF NERVOUS CONDENSATION RESULT HERE IN SOME "WASTED" REACTIONS.

are relatively near each other, the response resulting from the condensation is accordingly that of calling the ends of the thing "near" or the whole thing "short."

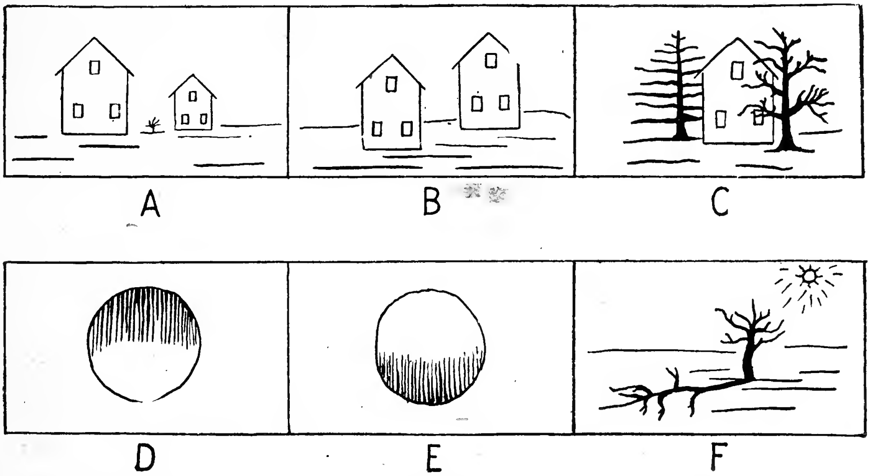
In S, on the other hand, the nervous currents representing the forks which spread out and inclose the triangle-shaped areas, when they play their undue role and enter strongly into the condensation of the nervous functioning, call forth a "wasted" response of naming the thing "long."

In T the end marks do not include such areas, which can either extend the figure or cramp its length especially. So the Other-One is likely to call S longer than T, and R shorter than T.

The space perceptions (or illusions) hitherto discussed are essentially two-dimensional space perceptions. That is, no express reference is contained in them to distances from the eye varying with different objects or different objective points from which stimuli emanate. Such reference to the third dimension, depth, or distance from the Other-One may, however, be said to have been implied, tho not expressed, when we spoke of the underestimation of the obtuse angles in the corner of a room and its ceiling. The Other-One there underestimates angles which are obtuse only because in reality their lines lie outside of the two dimensions of the field of vision in which they apparently lie.

Very numerous are those two-dimensional space perceptions (themselves substitutes for localizing reflexes, as we saw) for which in turn a "depth" localizing habit function is expressly substituted. The substitution, that is, consists in extending a limb farther or less far into the depth. Such substituted habit functions fully deserve the name of perceptions of the third dimension. (But there are other perceptions of the third dimension, to be discussed later, which are not substitutes for two-dimensional space perceptions, but for other reactions.) Of the two-dimensional space perceptions thus utilizable the following list contains those

with which everybody is most familiar. But there are many others. They are a most important subject of study for the artist in black and white and for the painter in colors.



TWO-DIMENSIONAL SPACE PERCEPTIONS REPLACED BY LOCALIZING IN THE THIRD DIMENSION.

1. Relative size of similar forms (A).
2. High or low position in the field of vision (B).
3. Transposition or cutting of one picture by another (C).
4. Shadow above (D), below (E), or on another object (F).
5. Indistinctness or lack of details.
6. Atmospheric perspective or change in coloring.

The smaller of two houses, instead of being called smaller in the field of vision, may be called more distant. A house, instead of being described as standing higher in the field of vision, may be called more distant than another house which appears lower. An oak tree which cuts a house is called nearer than a fir tree which is cut by the house. A round place in the wall, dark above and illuminated below

is called a depression—maybe one made by a cannon ball. If illuminated above and shaded below, it is called a protrusion—perhaps the cannon ball itself, fastened with mortar in the hole. The shadow of a tree on the ground, when the sun is beyond, gives to this patch of ground the name of "nearer." Indistinctness, lack of details on a person seen, is interpreted as greater distance in comparison with another person who shows more details. Mountains which appear bluish gray or lights which appear reddish (altho this feature is not form, but color, it may be mentioned in this connection) are called farther than mountains which appear greenish and lights which appear more whitish.

It is no wonder that the substitutions (these substitutions which so often are far more valuable to the Other-One than the replaced reactions!), after having become firmly established functions, sometimes proceed in the other direction. The following illustrates this. The moon stimulates on the retina an area of virtually the same size no matter whether it is high or low above the horizon. The atmospheric influences, when the moon is low, affect its color, but hardly the area stimulated on the retina. Why, then, does the Other-One call the moon larger, when he sees it low?

Now, to the Other-One the Earth is essentially a flat disk covered by a crystalline bowl, the sky. The moon is a luminous spot on this bowl. The depth of this overhead bowl is less than half its diameter. A bright spot at the rim (the far off rim!) of this bowl, which stimulates on the retina an area no smaller than that stimulated by a bright spot at the bottom (the near bottom!) of the bowl, deserves therefore to be called a spot much larger than the latter. Thus the Other-One calls the moon larger when he sees it at the horizon, at the rim of the crystalline bowl.

Being reddish helps a little in this illusion, for a lantern being carried away and disappearing finally in the fog becomes more reddish the farther it is carried.

We can ask the Other-One to convince himself by an experiment of the cause for calling that bright spot larger when he sees it at the rim of the shallow crystalline bowl. We make him look steadily for several minutes at a small piece of bright-colored paper on the table before him. When now he looks aside, he tells us that he sees an after-image. But when we make him look aside, we make him look, not only on the table, but also on the distant wall of the room. He then tells us that he sees the after-image on the wall much larger than on the table. This experiment shows again, that not only is a judgment of distance (that is, the action of calling a thing distant) often substituted for a judgment of size, but that also size may be substituted for distance by simply reversing the former substitution.

All these substituted actions to which we have referred above under the common title of "space perceptions of the third dimension" are undoubtedly habits, acquired. There is no reason for assuming that mere heredity enables the Other-One to call a thing (not necessarily by speech, but say, by any suggestive action) nearer or farther as soon as he has once acquired the habit of calling it by one or the other name found in the above list of two-dimensional space perceptions.

Not all visual space perceptions of the third dimension, however, are substitutions for space perceptions in the two dimensions of the field of vision. Some perceptions of the third dimension are substitutions for (or rather additions to) certain reflex movements which we have already more or less discussed when we spoke of the reflexes of adjusting our sense organs. The reflex of exposing the fovea

to stimulation and the reflex of accommodating the lens have such additional actions joined to them that they become habits of perception of depth.

If the lens is first accommodated for a thing at one distance and then for a thing at another distance, the action of calling one of these things nearer and the other farther can easily be added to the adjusting actions. What is added is a perception of depth, in accordance with the usual psychological terminology. We understand, of course, from all that has been said already, that the perception does not always consist in the pronunciation of a word, a name. It may as well consist in stretching the arm farther or less far, throwing a stone with more or less force, and so forth. In this case of accommodation it is not necessary, naturally, for the Other-One to have two eyes in order to perceive depth. Accommodation occurs also in the one-eyed person.

The reflex of exposing the fovea places the axes of the eyes so that they form the so-called angle of convergence. Instead of speaking of the "adjusting reflex of the retina," one might therefore speak of the "reflex of forming the angle of convergence." But, of course, the Other-One must have two eyes for this, since one line alone can not form an angle. He adds to the movement of forming this angle an appropriate reaction of the perception of depth.

Nature undoubtedly could have equipped the Other-One by heredity with reflexes of "localizing in more or less depth," making these reflexes dependent on and quickly following the adjusting reflexes of accommodation of the lens and of forming the angle of convergence. But there is no evidence that Nature did give the Other-One such equipment as a pure inheritance. These visual perceptions of depth all seem to be habits.

Still a further substitution of the same class, a further method of depth perception, is left to be discussed. It is among the most important, perhaps in life the preferably used, of the methods of perceiving depth. This is the so-called "stereoscopic vision." It is again a substitution for a two-dimensional space perception. But it differs greatly from all those already discussed (in our list above). In those only one eye was required. High and low position in the field of vision (figure B), for example, does not require the use of two eyes. It is perfectly obvious in a single eye's image.

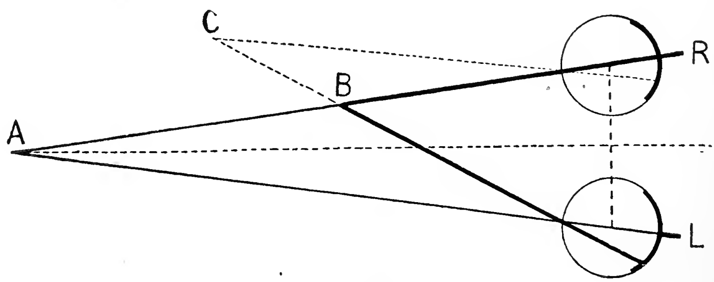
The perception of depth which is called stereoscopic vision is based on the fact that the two pictures of the two eyes are not identical. The existence of two different pictures being essential, the use of both eyes is then of course a requisite. The two pictures are not different in such a way that where there is a horse, for example, in one, there might be a cow in the other. The objects, the visible things, are the same. But in a lateral direction they do not have exactly the same places. (Vertically, the locations of the objects in the one eye's picture do not differ from those in the other.) The objects, or details of the objects, do not have exactly the same lateral distances from each other. And this fact can be utilized, as we shall see, for perceiving the third dimension with marvelous accuracy.

In order to understand stereoscopic vision well, it is necessary to understand the functional relations in general between the nervous currents coming from one retina and those coming from the other retina. We find there also certain problems concerning two-dimensional space perception which have not yet been discussed.

Having two eyes is a luxury so far as their use for localizing reflexly is concerned, where (disregarding such an-

atomical details as the "blind spot") the second eye can do nothing that the first eye could not do alone. Nevertheless, the Other-One not only has two, but carries them in such a position that most objects are pictured in both eyes and objects pictured in one eye and not in the other are decidedly a minority of little importance on account of their indistinctness. In general, then, we do not go far astray when we say that what is seen by one eye is also seen by the other.

Let us now consider one of the consequences of this arrangement. In our figure the two circles at R and L represent cross-sections thru the Other-One's eye-balls (who stands below us, if you wish, and whose eyes are seen from above thru a transparent skull). The median plane, the plane which divides his body into two symmetrical halves and passes thru the tip of his nose, is indicated in the figure by the dotted line lying between R and L. The object A, for example an electric light or an apple, sends



TWO EYES FIXED AND EXPOSED TO VARYING STIMULATIONS.

rays to the two "pin holes" and stimulates the retinas. The Other-One has a reflex of adjusting the axis of his eye so that it coincides with the direction of the most significant one of the innumerable surrounding stimuli. We assume that the axes of the eyes have thus adjusted themselves toward A; and we shall regard them as stationary

in our following considerations. In order to make them conspicuous, they (AR and AL) have been drawn some distance beyond the back of the eye ball. The object C also sends rays thru the pin holes. This object, from the point of view of the Other-One, whose eyes we see in our figure, lies on the right side of his median plane. It stimulates in each eye a point on the left part of his retina.

The reflex response to the excitation caused on either retina by A is a forward movement of the localizing hand along the median plane. The reflex response to the excitation caused on either retina by C is a movement of the hand somewhat to the right, tho mainly forward. All this is plain. But what is the result of moving the light C to the position of B? Nothing is changed in the left eye (we remember that we supposed the eyes to remain stationary) and the reflex response is still to the right forward. But the right retina is stimulated by B in such a manner that the reflex movement of the hand is straight forward in the median plane.

We already know that of two simultaneous nervous processes one is often swallowed up, so to speak, by the other. But this is not always the case. Assume that this does not happen here, that neither nervous process suffers a deflection. The arm, being pulled by certain muscles somewhat to the right, by other muscles straight forward, will then move according to the law of mechanics along the "resultant," not quite straight forward, but deviating slightly to the right. The hand will then probably touch, localize, the object B.

Now recall what we said about substituting one reaction, for example, the pronunciation of the word "one" or the word "two," for two localizing movements. Apply this to the movements localizing object A. The right eye calls

forth a muscular activity tending to localize A. The left eye calls forth exactly the same muscular activity localizing A. When for these two identical localizing reactions a single speech reaction is substituted, it naturally is the pronunciation of the word "one."

Now make the application to point B. The right eye, we said, calls forth a muscular activity tending straight forward in the median plane. But the left eye calls forth a muscular activity tending somewhat toward the right, since the left part of the retina is stimulated. When for these two different localizing reactions a single speech reaction is substituted, it is the pronunciation of the word "two."

Now imagine that B is the only object before the Other-One and that, after having heard him say "two" before witnesses, an evil-minded person, say, the attorney of the other side in a legal case where the Other-One is one of the litigating parties, localizes with his own arm—picks the apple, let us say—before the Other-One's eyes the object B. And immediately he asks the Other-One: "How many apples did I pick?" The Other-One answers "one," and the lawyer: "Then please pick the other apple, for you said a moment ago that there were two." There the Other-One stands, shamefaced. There is no other apple in sight. Of course, he cannot call himself a liar, especially here, in court. Think of the consequences! And besides, he has not been insincere. So he replies like a gentleman: "Excuse me. I was mistaken. I did not want to say it. I shall not say it again. I ought to have said there was one apple. In the future, I promise, I shall say in such a case, truthfully, that there is only one."

But now the evil one has him in his grip. While someone is momentarily obstructing the Other-One's view, he

hangs up the apples A and C, screening them so (by screens not indicated in the figure, to keep it simple) that A can not stimulate the left eye and C can not stimulate the right eye. "How many are there?" he asks. The Other-One remembers what he has promised. His retinas are stimulated exactly as they were in the former case by the apple B. He answers timidly "one." He expects that this answer will work better. But he congratulates himself too soon on his quick adaptability. He hears the lawyer's diabolical laughter while he picks two apples, A and C, gives them to the Other-One and asks him whether he will accuse him of having picked any apple that was invisible to the Other-One. The Other-One can not honestly accuse him of having done that. There the Other-One stands, confounded, having said "one apple" and holding two apples in his hand, exposed to the charge of being an habitual liar.

If we have reported these facts in a dramatic form, we have done that in order to draw some serious conclusions from them in a later part of this book, where we discuss hysteria and other abnormalities. Generally, under perfectly normal conditions of the organism, this kind of trouble is rather mild. Indeed in ordinary life, outside of the psychological laboratory, with perfectly normal people no such trouble as that reported above as having happened in court is to be feared. Why not?

The Other-One does not in ordinary life keep his eyes as still as they were supposed to be during the whole story. In ordinary life, when he says "one" or "two," his judgment is the combined result of innumerable successive stimulations of his ever moving eyes. The essential fact which we want to bring out in our discussion at this moment is not the possibility of trouble of a practical kind, but is the following.

Whether the Other-One applies to the objective situation to which his eyes are momentarily exposed the name "one" or the name "two," does not depend on whether the points stimulated on the two retinas are mathematically corresponding or not corresponding. During the second half of the nineteenth century it was fashionable among physiologists and psychologists to construct geometrically that peculiarly curved, bowl-shaped surface, for any possible distance before a person's nose, of which every point would stimulate the retinas in mathematically corresponding points. They called this surface the horopter. (One might translate this "locus of sights.")

The construction of the horopter was undoubtedly a good mathematical exercise, but its biological significance was not equal to the amount of the labor spent in constructing it. The correlation between the mathematically just corresponding or mathematically non-corresponding points on the retinas, on the one hand, and the speech reactions "one" or "two," on the other hand, is not absolute (as the theory and construction of the horopter assumes), but dependent on innumerable accidents of life at the moment in question. The correlation between correspondence on the retinas and the speech reaction has no absolute meaning, but a meaning only in terms of probability.

When the two points are mathematically corresponding, the probability of the Other-One's speech reaction being "one" is very great and the probability of his speech reaction being "two" is exceedingly small. In practice this means that to repeated questions "One or two?" he is heard to answer nearly always "one," very rarely if ever "two."

The less the two retinal points correspond mathematically, the greater the probability of his answering "two," while the probability of his answering "one" decreases ac-

cordingly. This means, for example, that with a certain deviation from mathematical correspondence the Other-One is found to answer repeated questions now by "one," only a second later perhaps by "two," a little later again by "one," and so forth; maybe as many times "one" as "two." With still greater mathematical deviation, he answers usually "two" and but rarely "one." However, the mathematical deviation may be very great indeed, and yet he may answer "one" as in the case above, where the answer "one" was—honestly—expected to work better in court, altho as a matter of fact it didn't.

Any one who does not object to poetical or figurative language, will permit us to compare the relation of the two retinas with the relation of two persons living together, say, husband and wife. The wife, having just bought a new hat, addresses her husband with: "Is not this hat beautiful?" The husband replies: "It is truly beautiful." They have but one opinion. They are in their domestic functions but one. They co-operate, do not compete. But suppose that the husband replies: "That hat looks like a bird's nest." They have different opinions. They are in their domestic functions two. They compete, they are rivals.

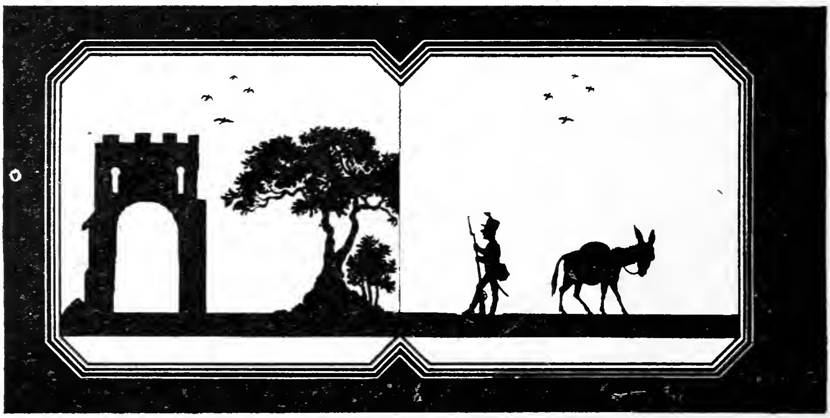
So your retinas sometimes compete; you then say "two." Sometimes they co-operate; you then say "one." In the nervous system this competition between two currents from the two eyes is equivalent to a small degree of "condensation" of the nervous functioning; co-operation is equivalent to much "condensation." The reaction is more likely to be a single reaction in the latter case.

One must not think, however, that there is never any retinal rivalry when the two points stimulated on the two retinas are mathematically corresponding. The following experiment will illustrate such cases without exhausting

them. The mathematically corresponding points are here stimulated in qualitatively different ways.

The three figures (each being double) must be given to the Other-One with the request to look at one half with the one eye and at the other half with the other eye. And the Other-One's remarks while looking during a few minutes must be carefully noted. Still better than to give him these little figures is it to give him larger sizes of them and to ask him to look at them thru an ordinary stereoscope.

In such a case as that of the soldier and the donkey appearing in the visual field of the right eye, the house and the tree in the visual field of the left eye, there is perhaps completely successful rivalry, a fight to the finish, in the sense that there is no co-operation based on a compromise. But it should then rather be called complete division of



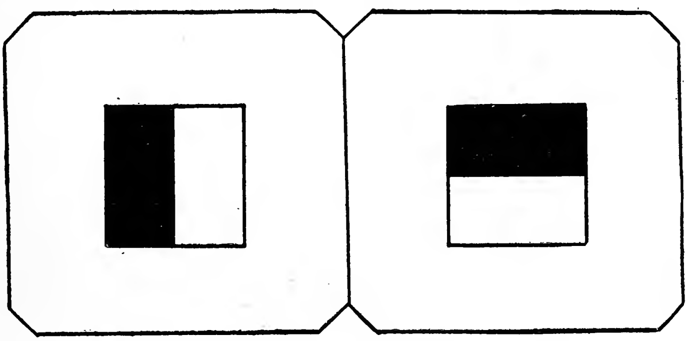
DIVISION OF LABOR BETWEEN THE TWO EYES.

labor than rivalry. The one retina says: "Here above is the foliage of a tree." The other retina, not receiving any stimulus to which a localizing movement upwards would be in order, instead of denying its existence, says nothing. The organism acts in accordance with the one order re-

ceived. With respect to the donkey, the roles, active and passive, of the retinas are exchanged; otherwise it is the same case. Competition here leads to complete submission of one of the competing parties. Such a relation between husband and wife might be the equivalent of perfect domestic happiness, but it would not be real co-operation. It is simply division of labor.

A similar illustration would be the presentation to one eye of one capital letter of the alphabet and to the other eye of another letter so that the organism would respond: "It is a monogram."

A little different is the case of the divided squares, half white, half black, one divided horizontally, the other vertically. In two of the four quarter squares there is perfect co-operation. "To the left above there is black," says the husband. "Black as pitch," confirms the wife. "To the right below there is white, snow-white," say husband and wife with the same unanimity. But with respect to the



IN PARTS THE RETINAS ARE CO-OPERATING, IN OTHER PARTS THEY ARE WRESTLING.

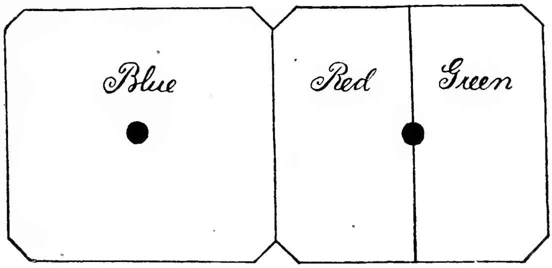
other two subdivisions there is rivalry. "There is black," says the husband. "There is white," retorts the wife. "No, there is black." the husband again; and so forth. And the household, the organism, carries out now the one order,

immediately afterwards the reverse, then again the first. That is, the Other-One, whose retinas are exposed, calls out: "It is black. No; no longer. A white cloud is passing over it. It is white now. But no, a black cloud is passing over it. It is black again." And all this within the brief time of a few seconds. The two retinas are wrestling, so to speak. For a moment one has the upper hand, a little later the other.

Sometimes, however, this rivalry leads, sooner or later, to a curious kind of co-operation based on compromise. "All right," says the wife, "if you insist, I shall call it black; but it is a rather luminous black." And the husband, with similar generosity: "All right, if you insist, I shall call it white; but it is a rather obscure white." And the household, the organism (that is, the Other-One whose retinas are exposed,) calls out: "It seems to be only one, a luminously-blackish-obscurely-whitish thing." Never mind the lack of logic in the combination of the epithets. Real life is not always logical. The Other-One might, of course, say that it is like a piece of black glass seen in the light of the day with the usual reflections of bright things surrounding him.

Similar and yet more different again is the retinal rivalry or co-operation when we use colors. Suppose you fill the Other-One's visual field of the left eye with blue, except that as an aid in the performance of the experiment there is a small black dot in the center of the field. The visual field to which the right eye is exposed has the same black dot in the center, but the right half of this field is green and the left half is red. The two retinas in this case co-operate rather readily with respect to the right half of the field. There is here much condensation of the nervous functioning for some reason which we shall mention

presently and understand well in a later chapter. The right half is pronounced to be a greenish-blue or a bluish-green. With respect to the left half of the field, however, the



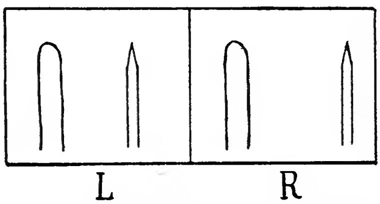
NERVOUS CONDENSATION DEPENDING ON SIMILARITY.

retinas usually function together in about the same manner as they did with respect to white and black in the former case, altho with a little more inclination toward a compromise. "It is blue," says the organism. "No, it is no longer blue. A red cloud has just passed over it; it is red. But a blue cloud is again passing over it." And so forth the Other-One's remarks. There is but little condensation, then, of the nervous functioning. Competition reigns, and deflection now in this, now in that direction.

Sometimes, however, that is, during certain moments alternating with those just described, the two retinas co-operate with red and blue too, compromise as they do with green and blue. The Other-One then pronounces the thing a reddish-blue, a violet, or a bluish-red, a purple. There is then an increased condensation of the nervous functioning. The fact that rivalry is less probable, less frequent, that condensation is more probable, between the green and the blue excitations than between the red and the blue excitations, is apparently due to the fact that the excitations green and blue, as we shall see in a later chapter, are in a lesser degree dissimilar than the excitations red and blue.

After these discussions of the functional relations of the nervous currents having their origins in the two retinas, we can quite readily understand that method of depth perception which customarily goes under the name of stereoscopic vision; and we therefore return to it now. We said in our beginning of its explanation that the reaction was in this case substituted for a perception of the difference of the place, of one thing laterally from another thing, in the one eye's field of vision and in the other eye's field of vision.

The Other-One, following our request, holds before his face a finger of his left hand and a pencil in his right hand. He holds, for mere convenience's sake, the pencil about twice as far from his face as the finger. And he holds the finger just a little to the left of the pencil, in order that the one may not obstruct the view of the other. We then ask him to close alternately either eye (but without mov-



STEREOSCOPIC VISION.

ing his head) and to draw a sketch of what he sees with the left eye and what with the right eye. In our figure we see this sketch drawn by him. L shows what he saw with his left, R what he saw with his right eye. L and R are plainly two different two-dimensional perceptions.

In order to record the special kind of difference between the two perceptions, we request the Other-One to draw in the field or frame marked I the pencil as it actually appears (at the finger's side) to the right eye; and then to

draw it also dotted in the position in which it would appear (at the finger's side) if this eye's image were, what it is not, an exact copy of the left eye's image. He draws figure I and tells us that obviously the pencil has suffered a displacement. We ask him to state in which lateral direction it has been displaced. He replies "To the right." We record the answer.

I. "The pencil (being farther) is displaced in the right eye's image to the right."

Now we request the Other-One to draw in the field II the pencil as it actually appears to the left eye; and then to draw it dotted in the position in which it would appear if this eye's image were, what it is not, an exact copy of the right eye's image. He draws figure II and tells us that obviously the pencil has suffered a displacement. We ask him in what direction it has been displaced. He replies "To the left." We record the answer.

II. "The pencil (being farther) is displaced in the left eye's image to the left."

Now we request the Other-One to draw in the field III the finger as it actually appears to the right eye; and then to draw it dotted in the position in which it would appear if this eye's image were, what it is not, an exact copy of the left eye's image. He draws figure III and tells us that the finger has suffered a displacement. We ask him in what direction it has been displaced. He replies "To the left." We record his answer.

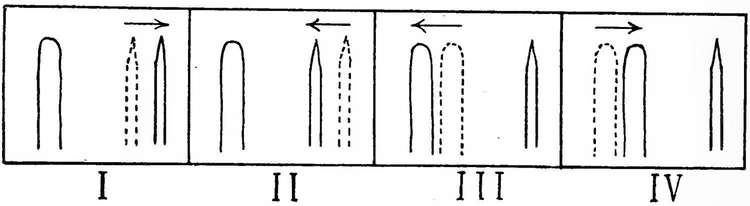
III. "The finger (being nearer) is displaced in the right eye's image to the left."

Now we request the Other-One to draw in the field IV the finger as it actually appears to the left eye; and then to draw it dotted in the position in which it would appear if this eye's image were, what it is not, an exact copy of

the right eye's image. He draws figure IV and tells us that the finger is displaced. We ask him in what direction it is displaced. He replies "To the right." We record his answer.

IV. "The finger (being nearer) is displaced in the left eye's image to the right."

Now we have in four distinct statements a complete description of all the difference which can be found to exist in the two perceptions due to the use of two eyes. I and II combined describe the perception of the lateral displace-



THE LATERAL DISPLACEMENT FOR A FARTHER AND FOR A NEARER OBJECT.

ment of the farther one of the two objects. III and IV combined describe the perception of the lateral displacement of the nearer one of the two objects. Of course, the term "displacement," we must never forget, refers always to the place laterally occupied by one object in comparison to another object. Speaking of a single object the term would be meaningless.

Experience, repeated innumerable times from earliest infancy, results in the formation of a substitution habit. The Other-One substitutes the reaction of calling a thing "farther" than another, when that thing, in the two dimensions of the field of vision, might be called "displaced in the right eye's image to the right and in the left eye's image to the left."

And the Other-One also substitutes the reaction of regarding a thing as "nearer" than another, when that thing

might be called "displaced in the right eye's image to the left and in the left eye's image to the right." These two substitute reactions, and nothing further, are the whole nervous function which is entitled in theoretical discussions "stereoscopic vision."

We understand from our preceding discussions that this substitution depends on the existence of a considerable and sufficient amount of condensation in the nervous functioning. How could the thing otherwise be pronounced to be "one, but farther" or "one, but nearer?" It would, when there is little condensation in the nervous functioning, be pronounced "a thing in this place and a second thing in that different place." And a substitution likely to occur would then be the pronunciation "two different things."

But one must never deceive himself by arguing that, logically, when for the pronunciation "two" the pronunciation of the judgment of "distance" is substituted, the former judgment of doubleness is thereby barred. Logic in this sense does not apply to nervous functions. We have found this before. "Substitution" may easily turn out only an "addition" when we study the reactions to given situations. The condensation of the nervous functioning may be so strong that the two retinas cease to "rival," that they "compromise" and call the thing "only one, but at a definite relative distance." This condensation may yet be insufficiently strong to imply that virtually no nervous flux goes to the motor points of the two separate reactions "this place" and "that different place." And then the Other-One makes us the illogical, but actual and frequent enough statement: "This one pencil seems farther than the finger, and at the same time I am inclined to say that there are two different pencils."

Of course, this result is the more to be expected—in other words, the condensation is the less likely to be strong—the greater the displacement, the greater the mathematical non-correspondence of the points stimulated in the two retinas.

To repeat: double vision is often simultaneous with stereoscopic depth perception. Double vision is not incompatible with stereoscopic depth perception.

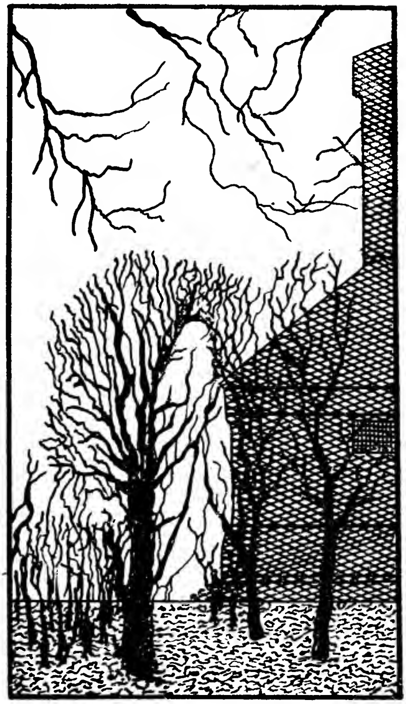
What has been said about the other perceptions of depth, should be repeated about stereoscopic vision. Nature might have given the substitute reaction to each individual of the human race as an inherited gift. But there is little doubt that Nature did not do it, and that the Other-One has to acquire stereoscopic vision as one habit among all the other habits of the perception of the third dimension.

Leaving now the discussion of depth perception as such, we turn to a brief statement about those space perceptions which are illustrated by so-called puzzle pictures. Here,—that is, in high class puzzle pictures, not in the bungled productions often published in Sunday papers—one of two possible perceptions is as likely to occur first as the other perception. But when one perception has once taken precedence over the other perception, the latter does not easily take the place of the former. This is natural, since the nervous current once strongly established, more readily deflects others, new ones, starting ones, than it is itself deflected by these starting ones. Besides, preoccupation plays its role.

Good puzzles of this kind do not require for their solution, for making the change, any turning of the page on which the picture is printed.

Once in a while such a puzzle picture can be obtained by photographing an actual situation. Such a situation is

then quite likely to cause practical troubles. The sketch here shown reproduces in its essential parts such a photographed puzzle. In a certain village of northern France the inhabitants, still somewhat affected by their experiences dur-



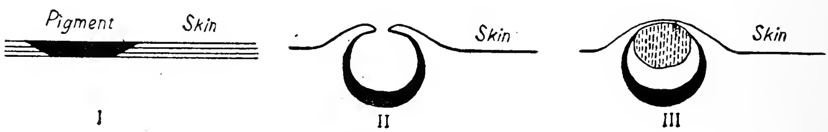
A "WASTED" REACTION.

ing the recent war, saw an appearance of the Virgin Mary in their church yard, among the leafless trees. Show the picture of the church yard to the Other-One and ask him if he sees the Virgin.

CHAPTER XI

Nature Divides the Spectrum for the Other-One's Space Perception at a Distance.

The retina is essentially a group of sensory points of the skin whose sensitivity has been peculiarly differentiated. The original eye is a pigmented area on the skin, as shown in figure I. The dark pigment absorbs the rays of light more efficiently than the unpigmented skin. During the process of evolution this area becomes a pit, obviously for its better protection, as shown in our figure II. Later a glassy body develops from the skin, as shown in III, closes the opening of the pit, and concentrates the light in a region always opposite that region in the field of vision



THE EVOLUTION OF THE EYE

from which the light emanates. The sensory points of this area are now very sensitive to ether waves of light. Such waves easily produce chemical changes in the sensitive cells of the two retinas.

But the problem with which Nature finds herself confronted is actually most complex. The object to which the organism is to react may not be different from the others because of its brightness, but on the contrary because of its darkness, its lack of light. The Other-One may be look-

ing for the blackboard in the schoolroom whose walls are painted white. Or the cave in which he usually finds shelter may—and surely does when seen from a distance—differ from the bluff in which it is located by its being a dark spot amidst brighter surroundings.

Nature, therefore, could not be satisfied with differentiating the sensitive cells in the retina merely so that they become sensitive to light. They must be sensitive to darkness too. A very particular (very complex and far from being exactly known, chemically understood) substance was developed by Nature in the sensitive cells. Following the example of others we call this chemical substance the Black-White substance. Its chief characteristic does not really consist in the fact that it is changed by light, but rather in the following more complicated fact.

When neighboring cells of a retina are subject to differing intensity of illumination, different chemical processes are set up, which are in some respect opposite. The resulting excitations, that is, are not merely differing in strength. Thus the very darkness of an object produces a very definite and really positive nervous process which passes along nervous conductors like any other nervous flux, and produces motor effects just as any other.

But why did we say that these positive nervous processes are in some respect opposite? What kind of opposition, not referring to the strength of each process, is this?

One can get an idea of the nature of this opposition by looking at the narrow moon sickle just before or just after the new moon. The large part of the moon which does not, like the sickle, receive the sun's rays, is illuminated by the "full earth" and should therefore in its totality appear brighter than the dark sky. But when you ask the Other-One about this, he calls only the regions at the cir-

cumference of the moon circle, bordering the dark sky, conspicuously brighter than the sky. The regions marginal to the sickle he calls even conspicuously darker than the sky.

We see thus that the intensities of the excitation Bright and of the excitation Dark are to a large extent independent of the absolute strength of the stimulating light and the stimulating lack of light. The strength of each excitation depends largely, if the other excitation occurs in the neighborhood, on the strength of that other excitation. We can say that there is observable, in adjacent regions of the retina, a phenomenon of contrast. And in this sense we can say that the two excitations in question, the one resulting from the stimulus light, the other from the stimulus lack of, or weakness of, light, are opposite processes.

Into the details of the theories concerning this rather complex and far from perfectly understood pair of excitations we cannot enter in this elementary book. It must suffice to state that there is considerable evidence to the effect that the excitation White and the excitation Black are chemically related in such a manner that they may be regarded as parts, constituents, of one chemical substance, which may be called the Black-White substance.

Let us restate then what we said before: Nature had to make a provision to the effect that (1) the presence or relative strength of a light stimulus and also (2) the absence or relative weakness of a light stimulus (when surrounded on the retina by stronger light) could each call forth a qualitatively distinct excitation often called "process." There are then (thus far) two visual processes. And Nature provided the animal race with one substance in the retina. Within this substance the Black process and the White process may co-exist, and may co-exist in greatly varying ratios of the intensities of each. To these ratios

the Other-One answers with "dark gray, medium gray, or light gray." The substance may conveniently be called the Black-White substance. But Gray substance would also serve as a convenient name.

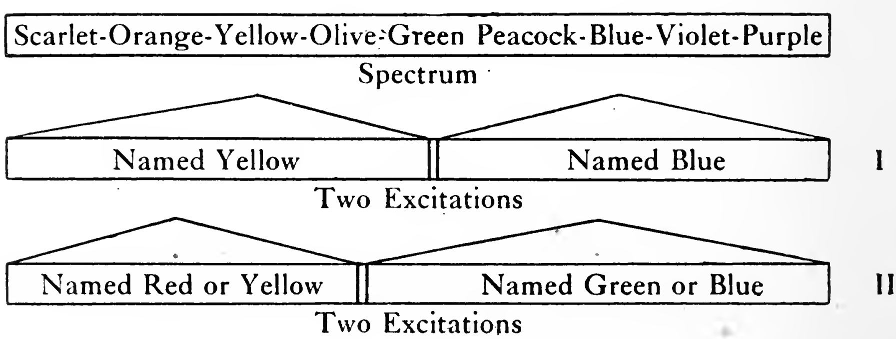
The visual substance just mentioned enables animals to localize reflexly a darker object on a lighter background or a lighter object on a darker background. But think now of a dark yellowish or reddish apple hanging on a tree with the usual dark greenish-bluish foliage. It might easily happen that the animal's, or the Other-One's, sensory points on the retina are then illuminated by the apple neither more nor less strongly than those other sensory points on the retina which are illuminated by the surrounding foliage. The ratio of the Black process and the White process would be uniform all over. There would then be no possibility of localizing the apple, of getting it.

But the light rays thrown back from the apple, altho not differing in intensity, may, and usually do, differ from those thrown back from the foliage. They consist of ether waves of different frequency, say, of lesser frequency. It is easily understood, therefore, why Nature furnished the animal race a second visual substance, in which again two different excitations could be called forth, but in this case differing according as the frequency of the ether waves was great or little. But where, then, is the division line between low frequency and high frequency in this respect?

When we speak of the totality of all those ether waves which are capable of exciting the retina, we speak of the "spectrum." The spectrum is an artificially produced array (usually, but not exclusively, produced by letting a ray of light pass thru a prism) of all these ether waves, or kinds of light. The light possessing the greatest frequency of waves we throw on one end, that of the least frequency on the other end of the array.

Nature could have made the second visual substance similar to the first in this respect that the two excitations, or processes, could co-exist in the same sensory cell, and the ratio of their intensities would differ according to the frequency of the ether waves, as according to the intensity of the ether waves it differed in the first visual substance. We should have found, there, much of the one excitation and little of the other at one end of the spectrum, much of the other and little of the one excitation at the other end of the spectrum, and about equal amounts of each in the middle. That would have served the localization of the apple in the above case perfectly. But Nature did not do anything of the kind with this second substance, but decided to confine one excitation to one side of the spectrum, the other to the other side, and to deny both to the place between them, near the division point.

Now, the frequencies of the ether waves in the spectrum do not spontaneously fall into two definite divisions. The change from greater frequencies to lesser frequencies is by infinitesimal, not by finite steps. Nature therefore had to



draw the line between the two divisions of great and little frequency rather arbitrarily to suit her ideas about this second visual substance. And Nature experimented, so to speak, before finally deciding where to draw the dividing

line; she tried drawing it here and drawing it there, as we shall see presently.

Above, the upper band, marked spectrum, represents the array of wave frequencies. If instead of writing the frequency numbers per second we have written familiar color names, this has been done only because the color names appeal more to the average person's fancy. These color names really serve here as nothing but frequency numbers, the lowest on the left, the highest on the right end of the band. Below this band there are two other bands marked on the right side I and II and each entitled "Two Excitations." These represent those two trials of Nature which we have evidence she made.

In I she drew the dividing line at the point Green. The ether waves to the right of this dividing line had to produce the one of the two excitations in question, first the more strongly (as indicated by the sloping line) the farther we pass to the right from the dividing line, then again more and more weakly until at the end of the spectrum the intensity of this excitation fades away. On the left side we have the other excitation, also possessing a maximum between two minima, more exactly between two zeros. The ether waves of the frequency represented by the dividing line do not call forth either of the two excitations.

Let us here indulge in a little fable. We have seen previously that the original purpose of any two differing excitations must have been the advantage of localizing objects. But at once another advantage offers itself, resulting from the existence of more than one excitation. Nature can now make an animal react to one of these excitations by one reflex movement and to the other by an entirely different reflex movement,—to give two among thousands of possible examples, to the one by opening the mouth, to the other by closing the mouth, or to the one by a positive

localization, to the other by a negative localization. Suppose some of the Other-One's ancestors at a remote stage of evolution, long before the existence of man, were able to speak, as in the fables, and were able even to foresee what names he nowadays would give to the different parts of the spectrum, and were given the task of choosing their own color names in such a way that they would suit best their offspring's modern color names. What would they do?

We assume that they possessed only the excitations thus far mentioned and not all of ours. They would know then that the Other-One would most frequently react to one of these excitations (in the case I) by saying "yellowish-red" (scarlet) or "reddish-yellow" (orange) or "yellow" or "yellow-green" or, rarely, "green." That is, nearly always by using Yellow. They would naturally choose the name "yellow." They would further know that the Other-One would, at this later period of history, most frequently react to the second of the two excitations last mentioned by saying "faint bluish-red" (purple) or "reddish-blue" (violet) or "blue" or "blue-green" (peacock) or, rarely, "green." That is, nearly always by using Blue. They would naturally choose the name "blue."

In the sense which we have just illustrated by a somewhat fanciful story we could say therefore that animals at a very early time had only the "blue" and the "yellow" color vision, that they did not possess the Other-One's fourfold color vision (blue, yellow, green, red) about which we shall have to say a little more in the next chapter.

But Nature made at least one other experiment with dividing the spectrum. The lower band, marked II, shows where the dividing line was located in this attempt. The Other-One's remote ancestors with those fabulous abilities of speech and foresight which we attributed to them would

have had to make a different choice, a less simple choice of names. The dividing line is here located in the part of the spectrum which their offspring now calls Olive. On the left he uses the names "yellowish-red," "reddish-yellow," "yellow" and "greenish-yellow," that is, always Yellow but very frequently also the term Red. On the right he uses the names "faint bluish-red," "reddish-blue," "blue," "blue-green," "green", and "yellowish-green," that is, very frequently either of the terms Green and Blue. Those ancestors therefore would probably have chosen to respond to the ether waves on the left side by calling them indiscriminately either red or yellow, and to those on the right side by calling them indiscriminately either green or blue, using for themselves the former two as synonyms and the latter two as synonyms.

The Other-One, transported back in history to that time, would have been astonished at this particular lack of discrimination and would have reported it in a letter to a friend by writing something like this: "Those ancestors of mine do not distinguish between red and yellow on the one hand, and do not distinguish between green and blue on the other. When one of them says that straw is yellow and the other says it is red, the first does not retort, but acts as if red and yellow were synonyms. And when a third person who just pricked his finger shows a drop of blood and exclaims: 'This looks like your straw,' they treat him as if he were a perfectly sane person. With respect to the words green and blue, and with respect to green and blue things, they act in the same queer manner."

All that we have said about the Other-One's remarkable ancestors changes from fable into reality as soon as we look around and find that some of these ancestors are living with us today. We call them color-blind. They de-

serve the name because in certain situations they act as if they were blind; for example, some of them may be as unable to localize by a reflex movement a certain red apple on a certain green tree as a blind person is unable to do that. We mean by color-blindness, physiologically, that the person in question has only the two visual substances thus far discussed, the Black-White substance whose two excitations depend on varying degrees of light intensity, and the second visual substance, a "color" or "chroma" substance, whose two excitations depend on the range of the vibration frequencies of the light. A color-blind person has an incomplete color sense. The Other-One's complete color sense, as we shall later see, presupposes a third visual substance with two further excitations within it.

When we said above that we had evidence that Nature made at least two trials of finding a suitable dividing line for the two excitations in the spectrum, we had in mind, not exclusively, but chiefly, the fact that these two types of color-blind persons exist; one type to whom all parts of the spectrum to the left of what we call Green are alike, but different from those on the right; another type to whom all parts to the left of Olive are alike, and all to the right of Olive are also alike, but different from those on the left.

The latter type, fully established, is very rare; the author of this, however, had the good fortune of having a perfect representative of this type under his own observation. But a very common relic of this condition still exists,—in every normal human being. It is a more important evidence of Nature's trial than a few rare cases of color-blindness. Ask the Other-One whether Red and Yellow, in spite of their dissimilarity, when compared with Green or Blue, do not seem to belong together, to be somewhat similar,—and the answer will be in the affirmative. And like-

wise Blue and Green, in spite of their dissimilarity, when compared with Red and Yellow, seem to have something in common, seem to be similar. A third fact belonging here is the habit of the artists of putting the former into one class and calling them warm colors, the latter into another class and calling them cold colors. This habit brings out the same distinction.

Much more common is the other type of color-blindness (in our fable mentioned first) which is represented by those to whom Scarlet, Orange, Yellow, and Olive are virtually meaningless distinctions, to whom it means nothing at all when the first autumn frost, leaving only a part of the foliage green, changes the larger part of the foliage in park and forest to yellow, orange, and even to a fiery red. Among a hundred men we are quite likely to find one of this kind. He does not object if you call all the autumn foliage simply yellow. We said intentionally "men," for we rarely find color-blind women. This color-blindness is a biological character which is sex-linked in a remarkable way. It is dominant (that is, observable) usually only in men, recessive (that is, not apparent) in women. And yet it is inherited, not thru a man (his father), but thru a woman (his mother). If a boy is color-blind, we usually find that neither his mother nor his father is color-blind, but that his mother's father is color-blind.

If a girl is color-blind, we usually find that her father and also her mother's father are color-blind. We understand thus why a girl is rarely color-blind. That depends on a rare case of ancestral mating.

We saw above (speaking of warm and cold colors) that the other type of color-blindness is in a mild sense a personal experience to every normal person. Even less foreign to everyone is this type. The normal retina may be

regarded as consisting of three concentric areas, a central disk, an intermediate zone and a peripheral zone. In the intermediate zone everyone has a colorblindness of this type, that is, all colors of the spectrum to the left of the point Green look alike, yellow, and all those to the right look alike, look blue. (Nothing in the spectrum ever looks here either greenish or reddish.) In the peripheral zone everything looks perfectly colorless, resembling an ordinary photograph or so-called half-tone print, some parts differing from others merely in being brighter or darker. In this peripheral zone the retina has only the Black-White substance. In the intermediate zone the retina has the Black-White and also the Blue-Yellow substance.

Only in the central disk has even the most normal individual his complete color sense, which presupposes a third visual substance. What the properties are of this third visual substance, we shall tell in the next chapter.

We owe to the German physiologist Hering the now generally accepted suggestion that the Blue excitation and the Yellow excitation are, not only different, but antagonistic in the sense that they cannot co-exist in the same sensitive cell. (We remember that the Black process and the White process can co-exist.) No uniformly colored thing is to be found in nature which the Other-One calls yellowish and bluish. Either one, or the other, or neither. Never both. If we mix artificially on a color-wheel a yellow and a blue disk (making sure that we do not choose a greenish-blue), we can change the proportions of the sectors so that the result is called bluish, or yellowish, or neither, but not so that the result is called bluish-yellowish.

Hering suggested that the two excitations making up this pair be called assimilation and dissimilation. Other terms, also frequently used and perhaps even more use-

ful, are recomposition and decomposition within the Blue-Yellow substance. When two forces act on a chemical substance, one tending to decompose and the other to recompose, and these forces are equally strong, nothing, obviously, would happen in that substance. So we understand why blue and yellow on the color-wheel cancel each other.

Even with a minimum of chemical knowledge one can make this clear to himself. Suppose you pour together, in liquid form, water and its two components, hydrogen and oxygen. Now put a good stopper on your bottle and do not let anything either get out or get in. Certain influences, however, can act on the contents of the bottle. Heat, for example, would favor composition. An electric current would cause decomposition. But both influences ("stimuli") acting together and with equal strength on this mixture (the Blue-Yellow substance, let us say) of a compound and its components, could in the bottle (the sensitive cell) increase neither the compound at the expense of its components (the process of recomposition) nor the components at the expense of the compound (the process of decomposition). Recomposition and decomposition are antagonistic. And thus the Blue excitation and the Yellow excitation are antagonistic.

Neither Hering nor anyone else has suggested whether the Blue excitation should be identified with the process of decomposition or with the process of recomposition; and the Yellow excitation accordingly. That can be assumed arbitrarily either the one or the other way.

The greatest value of Hering's theory of antagonistic chemical processes in the Blue-Yellow substance consists in permitting us to foretell that the Other-One will react in certain ways to certain situations, not yet described, and in finding that he actually does so react. These situations

we shall now describe under the names of (1) general adaptation, (2) successive induction, and (3) simultaneous induction.

Suppose we stimulate any definite group of the Other-One's retinal sensory cells in the same, unchanged, manner for five minutes or longer. For example, we ask him to keep his head and eyes perfectly still and then put before him on his writing desk a large piece of yellow paper, or we make him look steadily at a wall painted yellow. Suppose the retinal cells on which the yellow stimulus acts suffer the excitation which consists in decomposition of the Blue-Yellow substance. (Recomposition, then, is assumed to result whenever the stimulus is blue.)

Now, since the yellow stimulus remains unchanged, and since (we remember that the "bottle" is securely stoppered) the group of retinal cells has no more succor than a besieged city, the decomposition can not go on eternally. After a while it must cease, simply because there is no "compound" left to be decomposed. But, if you were the Creator, would you not regard this condition of the Other-One as a highly undesirable predicament? Yet it is unavoidable unless everything so far agreed on is changed entirely. There will inevitably come a time—no matter, whether in five, ten, or more minutes—when the Other-One no longer has, in that part of his field of vision, that excitation (the Yellow process) to react to. There will be a time when he tells us: "That paper (or wall) is no longer yellow."

But the least you would want to do for him, if you had the Creator's power, would be to put off that predicament as long as possible, just as the commander of a besieged city, or a farmer entirely snowed in, would put off the moment of surrendering to the enemy, or to starvation.

The usual method is rationing of the supply. And so the eye is made in such a manner that it will give up at a steadily diminishing rate the recomposed material to the stimulus for being decomposed. The eye, we may say, spontaneously resists more and more the process of decomposition and thereby delays its complete cessation.

The Other-One, accordingly, long before he tells us that the paper has ceased to be yellow, is found to remark again and again that its yellowishness has become weaker and weaker and weaker. Of course, the experiment with blue would have yielded the corresponding result.

What we have just described, deserves to be called, and is called, a "general adaptation" to the exigencies of a situation. Why it is called "adaptation," is immediately clear. It is called "general" merely because one of the other two phenomena to be described, the one called "simultaneous induction," is sometimes also called "adaptation" and then, for the sake of distinction, "local" adaptation.

Suppose now, our above experiment being finished, we permit the Other-One to use his eyes freely. The region where all recomposed material of the Blue-Yellow substance has been changed into decomposed material could then not function normally. A perfectly normal function does indeed presuppose a perfect balance between the available quantity of the recomposed and the decomposed material. But when of the one kind there is absolutely nothing, the condition of the retina is extremely abnormal. How can it most quickly be made normal again?

The general supply store, so to speak, of any part of the body is the blood. For example, if a bone is broken and bone building material is needed, it can be, and is, obtained from the blood. But needed material can be obtained from the blood only slowly. We know that it takes

more than days—weeks and even months—to heal a wound or a broken bone. It might take hours or days to replenish the sensory cells. Now think of the farmer snowed in. If it takes too long to get a chemical substance, say soap, from the store in the town, and he has grease and wood ashes, he quickly makes the soap himself. And the sensitive cells have plenty of the raw material from which the compound needed can be made. The raw material in this case is the decomposed material. And there is enough of it in the cells. Indeed the very complaint is that there is too much of it.

So Nature, in order to solve the problem, should have enabled the sensitive cells to restore spontaneously the balance between the quantity of the decomposed and the recomposed material. And Nature has enabled them. And at once, therefore, when the yellow stimulus is removed, the eye spontaneously sets up the antagonistic process. But the antagonistic process, recomposition, is the Blue excitation. To it the Other-One can hardly help responding in the normal way. So he tells us: "Whatever patch in the room (other than that yellow patch) I now look at, on the ceiling, the floor, my arm (and where not!), it is blue."

This phenomenon is called successive induction. The term "induction" was borrowed by Hering from physics, where we are accustomed to speak of electrical induction. And it is called "successive" naturally because the Other-One's remark that the patch in whose direction he looks is blue succeeds his remark that the patch in whose direction he formerly looked was yellow. Of course, if the first color name had been blue, the second would have been yellow. Yellow and blue are in the description of this phenomenon entirely interchangeable.

The third phenomenon we promised to describe, can also be deduced from the theory simply as an economic necessity. If the farmer needs soap, needs it soon, and has plenty of the raw material, but cannot boil it in his own house (the yellow stimulus prevents the blue excitation in certain sensitive cells,—the "patch"), he may take the raw material to a near neighbor's house, boil his soap, and take it back home even before his soap supply has become completely exhausted. The retinal "patch," while decomposed material more and more accumulates in it, sends it over its border, has it recomposed on the other side and sent back in a steady stream to be decomposed again.

This will naturally result in two facts. First, along the border on the patch the rationing need not be as severe as farther inside. That is, along the border on the patch the Yellow excitation is stronger than farther inside. And just outside the border, in a marginal region, the Blue excitation occurs in spite of the absence of an adequate stimulus. The Other-One tells us that the marginal region of the patch is yellower than the inside of the patch, and that it is surrounded by a blue margin.

This phenomenon is called simultaneous induction, because the blue outer margin and the yellow patch with its intensely yellow inner margin appear simultaneously.

The marginal character of simultaneous induction can easily be concealed by avoiding patches and instead composing the field of vision of alternate yellow (or blue) and gray stripes, making them narrow enough so that the margin on one side just overlaps the margin on the other side and renders the coloring of each stripe uniform in its entirety. The Other-One, then, when asked whether he sees the field of vision composed of yellow and gray stripes, tells us that this is not so; but that the alternate stripes are yellow and blue.

The theory, or rather hypothesis, of Hering, assuming two processes (excitations) of recomposition and decomposition in the single Blue-Yellow substance, is a beautiful explanation of the four facts of antagonism, general adaptation, successive induction, and simultaneous induction. But the division of the spectrum which we have discussed in this chapter is not a mere hypothesis, but a fact referring to uncounted observations of the Other-One's reactions to visual stimuli when the latter are taken from the spectrum.

CHAPTER XII

Nature Makes a Second Division of the Spectrum.

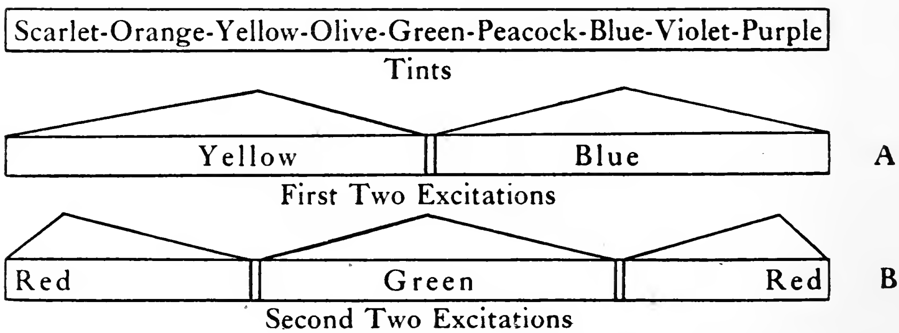
Perhaps Nature made a mistake in preferring the method of dividing the spectrum between the two excitations, to the method of changing the ratio of the two excitations gradually from one end to the other end of the spectrum. If Nature could use two excitations, co-existing, but varying in ratio, for all the shades from white to black, Nature surely could have used also two other excitations, co-existing, but varying in ratio, for the scale of frequency of the ether waves.

The mistake consists in preferring a merely two-fold division to a many-fold, indeed unlimited, division based on a ratio whose variations are unlimited. A poppy flower in a wheat field is then found to be not localizable because the ether waves coming from the flower and the wheat lie in the spectrum on the same side of the division line.

In order to remedy this (generally not vital, but nevertheless undesirable) defect, what can Nature do? We discover that Nature, in order to improve the frequency discrimination of the ether waves, has actually made a second division of the spectrum within the "Yellow" region of the spectrum. For this purpose Nature has had to introduce a third visual substance. And she has selected this third visual substance in such a manner that within it again the phenomenon of antagonism exists. That is, the two different excitations within it are again of the nature of recomposed and decomposed material, each one changeable into the other.

Now, in looking for a chemical substance which might serve as this third visual substance, Nature made a very queer choice. She selected a substance which—if it is not the Yellow excitation itself, that is, the part of the Blue-Yellow substance whose increase calls forth the response "yellow"—certainly is about the same thing as the Yellow excitation. This selection, we shall see presently, has a very strange consequence.

First, however, let us look at a diagram showing the point of the spectrum where the division is made within the Yellow region. This region is shown in the band marked A on the right, which is identical with the band marked I in our former diagram.



The right half of the region of the Yellow excitation is called by the Other-One greenish, especially toward the right where its yellowishness is less pronounced. The left half of the region of the Yellow excitation is called by the Other-One reddish, especially toward the left where its yellowishness is weak. But the middle of this region naturally is not called by the Other-One either reddish or greenish, since there neither the Red process nor the Green process is in existence. He calls it purely yellow.

Now let us return to the strange consequence of Nature's selection of something virtually identical with the Yellow

excitation, to serve as the third visual substance, as the Red-Green substance. We ask the Other-One to mix on a color-wheel a red (and not at all yellowish) disk and a green (and not at all yellowish) disk in such a manner that the result is neither red nor green. This can easily be done with just a little care and patience, for in the Red-Green substance recomposition and decomposition exclude each other. He adjusts the sectors, taking less red if it still looks reddish, less green if it still looks green. Finally he pronounces it to be neither red nor green. But if we ask him if it is now absolutely colorless, he tells us that that is far from being true. He tells that he would call the disk spinning before his eyes a kind of yellow,—not straw yellow, to be sure, but some rather dark and muddy looking yellow, but yellow nevertheless.

This result seems very strange, but loses its strangeness as soon as we remember how Nature selected the Red-Green substance. She made the Red-Green substance simply by taking the Yellow excitation and modifying it very slightly, if at all. Now when a red and a green disk are mixed on the color wheel so that neither the Red excitation nor the Green excitation (neither recomposition nor decomposition in the Red-Green substance) are allowed, a disturbance of some sort nevertheless is created in a substance which is virtually the Yellow excitation. And this disturbance of the entire Red-Green substance seems to be passed along the nervous conductors with about the same effect as if the normal Yellow excitation had been created within the Blue-Yellow substance and were being passed along the nervous conductors.

Having divided the Yellow region of the spectrum, Nature would—we should expect—divide the Blue region, too, of the spectrum and thereby introduce into the eye a further visual substance. She divides this region indeed, but dis-

covers, we may say, that it is unnecessary to introduce a fourth visual substance. She discovers that, for some cause, the third, the Red-Green substance, suffers recomposition in one of the halves of the Blue region of the spectrum, and decomposition in the other half of the Blue region. The same Red-Green substance is therefore selected to serve also for the divisional discrimination of the two parts of the Blue region of the spectrum.

The Other-One, as is indicated in the band B of our diagram, calls the left part of the region of the Blue excitation greenish, especially toward the left, where its bluishness is less pronounced. He calls the right part of the region of the Blue excitation reddish. But the middle of this region he naturally does not call either reddish or greenish, since there neither the Red process nor the Green process is in existence. He calls it purely blue.

Speaking of the entire spectrum, we must say, in accordance with B in the diagram, that the whole central part is by the Other-One pronounced to be greenish and both ends, right and left, reddish.

Now we understand why the Other-One shows so much admiration for the great variety of coloring exhibited by spectrums, for example, by that spectrum which is a frequently seen natural phenomenon,—by the rainbow. One extreme he calls yellowish-red (scarlet). This extreme lies in our diagram on the left. Passing to the right, he tells us that the scarlet becomes more and more yellowish, until he inclines to give it the name of orange. Passing further to the right, the orange loses more and more its reddishness and becomes a color best described by the simple name yellow. Passing on, the yellow assumes a greenish tinge, becomes olive, and then green pure and simple. This happens where the Green excitation is quite free of any admixture of either the Yellow excitation or the Blue excita-

tion. Passing along in the spectrum, bluish-green appears, called peacock. Blue takes its place. A slightly reddish blue follows (violet) and with a somewhat more reddish blue (purple) the spectrum fades away.

An interesting and notable fact is the absence from this spectrum of anything that the Other-One would call a pure red, that is, a red being neither in the least yellowish nor in the least bluish. Neither does nature's spectrum, the rainbow, contain all the colors of nature, altho it may be said to contain nearly all of them. This red, lacking in the spectrum, can be produced easily enough on the color wheel. Just add to scarlet (which is a slightly yellowish red) a small sector of blue, enough to cancel the yellowishness of the scarlet without adding any bluish tinge.

There being four excitations in the two "color" substances (not counting here the Black-White substance), there must occur, in the Other-One's life, occasions in each of which he will not need more than a single one of the four color names invented to suit those four excitations. But there will also be occasions in each of which he will need two color names. One can represent this fact graphically by a square (this square appears incidentally on the right in the following figure) of which the four corners stand for the four color names when used alone, and the four sides stand for the four possible pairs of color names, red-yellow, yellow-green, green-blue, and blue-red. That the two pairs red-green and blue-yellow are impossible color names, we have already learned in discussing the fact of antagonism.

The color square suggests a principle of classifying all the colors, that is, all the colored things of nature, by dividing them into those standing at the corners of the square and those standing at the sides between the corners. We

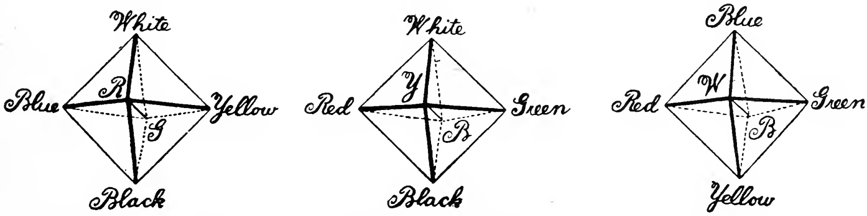
thus obtain the two groups of the "singular" colors (requiring only a single color name) and the "dual" colors (requiring a double color name). As we distinguish in the grammar of many languages a singular, a dual, and a plural, so we might feel inclined to suggest to the Other-One to use also plural color names. But he has no use for them, because of the fact that the four excitations fall into two pairs of antagonistic excitations. This fact prevents any three of the four from ever occurring at the same moment in the same retinal cell. And of course, it also prevents all four from thus occurring. Thus, there can be in the Other-One's world only singular colors and dual colors, and no plural colors. He speaks to us only of four singular colors and of four classes of dual colors, each of these classes of dual colors containing infinitely many tints.

It is interesting to note in this connection that only the names of the singular colors are of such ancient origin that absolutely nothing can be said of it except that these names must have their source in elementary biological needs. All other color words of the dictionaries, other than red, yellow, green, and blue, have an etymological history. That is, they meant something else, a fruit, a flower, an animal, a mineral, and the like, before they came to mean a color. Think of orange, olive, violet, peacock, maroon as examples. In some cases this is not so obvious, but nevertheless true. Purple seems to have no meaning other than color. But it is actually an ancient corruption of the name of the mollusc which the Phoenicians collected in order to extract a bluish-red pigment.

If we want to represent in a graph that part of the Other-One's color nomenclature which is indispensable as soon as we include also bright and dark discrimination, we need a graph of three dimensions. The two dimensions of

the color square are insufficient because the one co-ordinate represents the Red-Green substance and the other co-ordinate the Blue-Yellow substance. We need a third co-ordinate to represent the Black-White substance.

The simplest body to include all the three-dimensional color names ("color" in the broader sense, including white and black) is a regular octahedron. (A detailed study of the Other-One's color nomenclature would lead us to prefer a somewhat less regular, tho similarly shaped body. But in this book there is no room for these details.) Why is it an octahedron, that is, a body that tapers off into a



THE VISUAL EXCITATIONS EXHIBITED IN AN OCTAHEDRON.

point whenever we proceed from the origin of the co-ordinates in any one of the six directions? In the left octahedron of the figure we see why this must be so for proceeding toward Red or Green. An "intense" or "fully saturated" red is never excessively bright or excessively dark. Therefore, in increasing its reddishness, we limit the available space between White and Black until we end in the very point marked Red. The same statement holds for Green.

And also, as we saw in the spectrum, the more we confine ourselves to the neighborhood of the Green point, the less there can be of the excitations Yellow or Blue, for the Green point is the very division point of the spectrum between these two excitations. The same can be said of the

Red point if we think of the spectrum as a ring in which the right and the left end are joined in a single point of the ring.

In the octahedron standing in the center we see why the color body tapers if we proceed from the origin of the co-ordinates in either the direction Yellow or Blue. The more saturated a yellow or blue, the less chance there is in the Other-One's experience for its being excessively bright, dark, red, or green.

The octahedron on the right shows that the body tapers when we rise above or submerge below the "color square." An excessively bright or excessively dark object never appears reddish, yellowish, greenish, or bluish, or in any dual coloring. So much for the fact of experience. However, any reason for this fact, any theoretical explanation, cannot be given either very convincingly or in very simple terms. We therefore pass over it.

This octahedron (or a more irregular, but similarly shaped body which may take its place) is usually referred to, for purely historical reasons, as the "color pyramid."

We pointed out, in the preceding chapter, that the three visual substances, which are represented in the three dimensions of our octahedron, have their natural geometrical representation in the three "zones" of the retina. Nature, introducing the Black-White substance in the eye, spread it out over the region called the retina. The Blue-Yellow substance was introduced much later in evolution, and Nature, it seems, has not yet found the time to spread it, from the center in a radial direction, farther than the peripheral limits of the intermediate zone. And the Red-Green substance has not yet been spread by Nature beyond the limits of the central disk. Only in this central region, therefore, does the Other-One possess the three visual substances

represented in the octahedron. In the surrounding zone he is "color-blind" in the ordinary meaning of this term; that is, he has no Red-Green discrimination. And in the peripheral zone he has no frequency discrimination of light whatsoever.

We also understand why the ordinary type of color-blindness, discussed already in the preceding chapter, consists in the lack of the Red-Green (and not in the lack of the Blue-Yellow) discrimination. It seems logical that individuals lacking an evolutionary character of the race, should be more likely to lack a character lately acquired by the race than a character older and, as stands to reason, more firmly established.

A few color terms which we hear the Other-One use after he has gone thru certain occupations common in human society, should still be mentioned.

"Complementary" is the name given to any two colors which can be mixed so that the result is "colorless," that is, neither reddish, nor yellowish, nor greenish, nor bluish. The name has an historical origin, referring to the fact that colorless compound light, like sunlight, can be physically split in infinitely many ways into pairs of colored light, and that any two "twins" of this kind can again be physically combined into the "complete" light, that is, the unsplit and colorless light. ("Complementary" is derived from the word "complete," not from compliment.)

There is no scientific relation whatsoever between complementariness and antagonism. The former is a physical, the latter a biological term. The only and fortuitous relation between these terms consists in the fact that one of the many pairs of complementary lights of the physicist looks like the one pair of singular colors, yellow and blue. It is especially important to remember that there is no pair

of complementary lights which looks like the other pair of singular colors, red and green. If one light looks like the singular color red, its complementary light would look like the dual color bluish-green. And if one light looks like the singular color green, its complementary light would look like the dual color bluish-red.

Sometimes we hear the Other-One speak of certain groups of colors as "primary, principal, fundamental, or original" colors. All these terms are entirely dispensable for the psychologist, to whom the distinction between singular and dual colors is the only one needed. But naturally, if the psychologist were pressed to tell his idea of the Other-One's "primary, principal, fundamental, and original," as distinguished from the Other-One's "secondary and derived," color experiences, the psychologist could do nothing but call his four singular colors primary, etc., and the dual colors secondary, etc.

But the technologist, the man engaged in industrial color work, such as color photography, color printing, etc., would find an entirely different group of colors most interesting, that is, most primary, principal, fundamental, and original, to him. In technology the chief problem is to find the smallest numbers of colors (that is, usually, pigments) which can be mixed in such varying manners that all the tints of nature as well as a colorless impression may result. The smallest number fulfilling this condition is three. There are, however, infinitely many "triplets" of colors fulfilling this condition. Among them the technologist usually, but not always, uses scarlet, violet, and green, because of certain advantages with respect to the saturation of the resulting tints. These three then are to him his chief or "primary" colors.

A simple method of finding a triplet fulfilling these technological conditions consists in selecting two singular, but not antagonistic colors, and adding that dual color which resembles the two singular colors left out. For example, blue, red, and yellowish-green. It is then easy to demonstrate that this triplet fulfills all the conditions. From yellowish-green we easily get, by adding some blue, the singular color green; and also, by adding some red, the singular color yellow. Having then all singular colors, we can easily get, by combining them, all possible tints and also the colorless impressions. But all such triplets of colors, we must not forget, are of importance only in technology, not in psychology.

The artist, the painter, again has a different notion as to what colors are "primary, principal, fundamental, and original" to him. The painter would like to have as many different pigments handy on his palette as there is room for, since this facilitates his work. But the space on the palette is limited, and having to buy and store away many tubes or cakes is inconvenient and uneconomical. So he tries to restrict himself to buying a limited number of pigments. He rarely, if ever, restricts himself to less than six. So the Other-One, having asked a painter what his "primary" colors are, without which he would not care to begin any painting, is quite likely to have heard that there are six primary colors. To the psychologist this is of very little interest.

Everything that we have said in the preceding chapters about antagonism, general adaptation, successive induction, and simultaneous induction, applies to Red and Green with proper modification as it applied to Blue and Yellow. And it applies, with the exception of antagonism, even to Dark and Bright.

There are innumerable other facts which we might discuss, concerning the Other-One's observed behavior of giving this or that name or significance to this or that situation to which his eyes are exposed. We select only one to mention here, the fact of "positive after-images." A color reaction of the Other-One due to successive induction is often called a "negative after-image" because the induction stimulus causes the Other-One to give the "image," that is, the object seen, "afterwards" a name which is "negative" in the sense of being due to antagonism or to the opposition of darkness and light. What, then, is a positive after-image?

It happens that the Other-One calls the object, "after" it has disappeared from its former place in the field of vision, by "the same" name, implying its continued and unchanged existence. For example, we notice that the Other-One does this when he looks at the setting sun and then turns his head away; or when the stimulus is the glowing filament of an electric light bulb. He tells us that the sun or the glowing filament seems to be still present.

The positive after-image is in one respect the opposite of "general adaptation." In general adaptation the excitation ceases before the stimulation ceases. But in the case of a positive after-image, the excitation outlasts the stimulation.

The stimulus must always be very strong if it is to cause a positive after-image; or, if not very strong, very prolonged. A weak stimulus gives only a negative after-image. A strong stimulus, however, gives both. The positive after-image is always followed by a negative after-image. Sometimes the Other-One tells us that that negative after-image which follows a positive after-image, might more properly be given the name of a "flight of colors."

The three visual substances, when strongly disturbed by intense stimulation, seem to pass thru a sort of "see-sawing" process before regaining their quietness. The Black-White substance see-saws thru an alternate prevalence of the Dark excitation and the Bright excitation; and the two color substances see-saw thru an alternation of recomposition and decomposition. But the lengths of the periods of see-sawing are different for the three substances. The total result is a combination of excitations which varies from moment to moment, and in which it is difficult to find any orderliness. To it the Other-One is apt to find it impossible to react otherwise than by simply calling it a flight of colors.

The phenomena of adaptation and after-images may be written in their logical relations in the following form.

General Adaptation			
Local Adaptation	Simultaneous Induction		
	Successive Induction	Negative After-Imagery	
		Positive After-Imagery	

The terms which, in the above form, stand side by side on the same level, are simply synonymous. The terms which stand directly above and below each other are thus placed to indicate that their relationship consists merely in the fact that the one suggests the other logically.

It may appear strange to us that Nature should have chosen the visual substances and the excitations within them in such a manner as to call forth these "wasted reactions," the color illusions described. But an excuse for Nature is the fact that these illusions are not as common in the Other-One's life as they appear to be from a theoretical study like this. They depend for their full development at any moment on a restful position of the eyes which is but rarely realized outside of the scientific laboratories where it is

specially fostered. Nature has overcome the difficulty created by the possibility of color illusions by making the eyes such movable and extraordinarily restless organs as they are.

CHAPTER XIII

The Other-One is Equipped with a Sense Organ Particularly Suited to Signals.

In a previous chapter we enumerated the most interesting reflexes. We found among them a group of special importance, the reflexes of signaling. The signaling reflexes are indispensable for social life. And we stated that the various species of animals had been equipped by Nature also with special reflexes enabling them to respond properly to these signals coming from other individuals of the same species or of a different species.

A reflex, we know, presupposes a chain of nervous conductors leading from a definite sensory point to a definite motor point. But it also presupposes that this motor point is properly equipped with a motor organ. And it further presupposes that the sensory point is adequately equipped with a sense organ.

We learned that in general the most efficient signals are acoustic signals. We therefore ask, now, what Nature has done in order to enable animals to respond properly to acoustic signals. When the acoustic signals are complex and the proper reflex (or habit) response depends on condensation of the nervous functioning called forth by a multiplicity of acoustic signals, we speak of "perception," and here customarily of "auditory perception." We can, therefore, repeat our last question in the following form: How has Nature equipped that sense organ upon which the Other-One's social reflexes particularly depend, that sense organ which serves the Other-One's auditory perceptions, his "auditory organ" or, briefly, ear?

An acoustic signal is a trembling motion of an object capable of causing in the elastic medium surrounding it (air or water) a periodic density change. It is one of the laws of physics that a periodic density change will then occur, after a very short time, also at any other place within the elastic medium, provided the distance of this other place is not excessive.

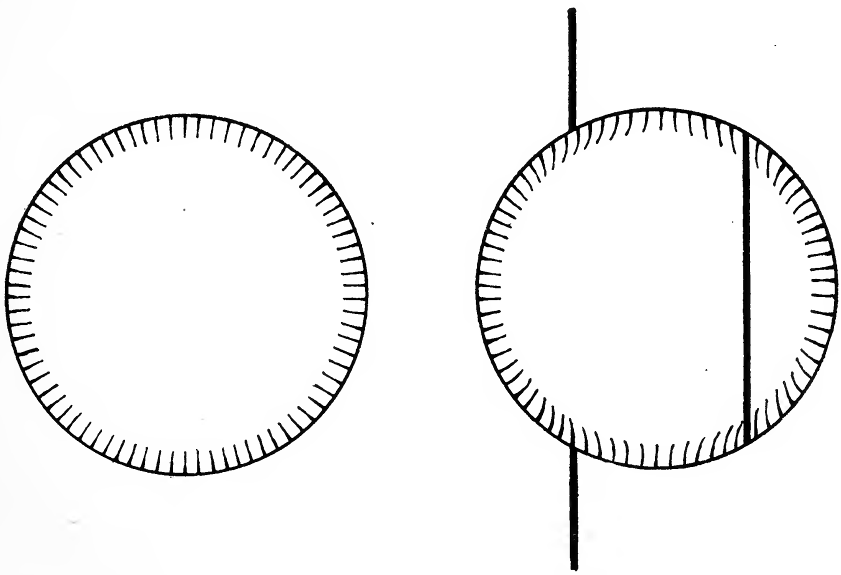
Nature's first problem then consisted in modifying the skin of animals living in water or air so that density changes, that is, pressure changes, of the water or air could very easily bring about in sensitive cells chemical changes, —excitations. The so-called lateral-line organs of the fishes are such modifications of the skin.

However, the pressure changes acting ordinarily on the lateral-line organs of the fishes are still very great in comparison with the pressure changes which we call sound, caused by minute trembling motions of objects at distances often very considerable. Nature found that a sense organ of extraordinary sensitiveness could be constructed by letting the sensitive cells end in fine hairs and by exposing these hairs in such a manner that the slightest pressure changes in the medium surrounding the animal would effect a bending of these hairs.

A very simple sense organ of this kind is a cavity, located within the animal's body or near its surface, having a fur-like lining and being filled, of course, with the common fluid of the animal, with lymph. Our figure shows two views of such a cavity. In the left part of the figure the hairs are all in the normal condition, straight. At the left is a density wave approaching. It has already reached the interior of the animal, but not yet the cavity in question. The right part of the figure shows the effect on the hairs of the passage of the density wave thru the cavity. The wave

is not likely to pass thru the lymph of the cavity with the same velocity with which it passes thru the substance of which the wall of the cavity consists. The velocity may be greater or less. That depends on the physical conditions of the animal's anatomy. What is important for us to keep in mind is merely that the velocity is not likely to be the same.

In our figure the velocity in the lymph is supposed to be greater. The wave surface has advanced in the lymph farther to the right than in the wall of the cavity. The particles of the substance have been pushed together and the hairs between them have had to follow, bending to the right. Of course, the bending is exaggerated in the figure. Behind, that is, to the left, just the opposite is observable at this moment. The particles of the wall are being pushed



AN EARLY STAGE IN THE EVOLUTION OF THE AUDITORY ORGAN.

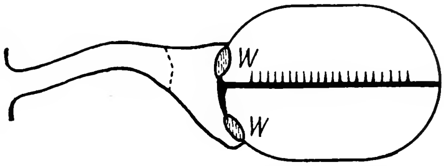
together, into greater density. The roots of the hairs are here farther to the right than their tips. That is, the hairs are bent to the left. It is worth mentioning that this kind

of "hair organ" not only can be very sensitive to small density changes, but also is capable of being affected no matter in what direction the density waves pass thru the cavity, since the "fur lining" covers all walls of the cavity and is thus equally exposed in all directions.

The Other-One's "ear," we shall presently learn, is much more complicated than such a hair lined cavity. But the essential features of this simple hair organ are present within it. There can be no doubt that the Other-One's ear, while functioning in a far more complicated manner, in accordance with the purposes of its anatomical structures, functions at the same time in this primitive manner described. The complicated function, that is, does not preclude the primitive function. And when the Other-One, in the course of a disease, loses the more delicate and complicated functions of his auditory organ, he may still retain the organ's capacity for this primitive function. Many strange observations about the hearing of people who are hard of hearing or almost deaf, become thus understandable.

This primitive "hair organ" was further developed by Nature in the following manner. The cavity was enlarged. The "fur lining" was removed from the wall and floated within the cavity, not quite freely however, but attached to the walls in such a way as to form a sort of partition dividing the cavity into two rooms. To each of these rooms a window was given. These windows open upon a tunnel which leads out into the surrounding medium, the water or air in which the animal lives. But the distance from the outer air (or water) to one of these windows, both marked W in the figure, is somewhat greater than to the other window. The result is that the incoming density wave never exerts its maximum pressure upon both

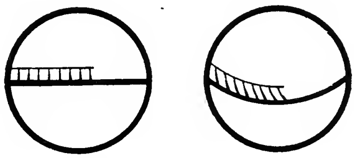
windows at exactly the same moment, but first upon the one, later upon the other, and so on alternately. Consequently the lymph in the cavity is pushed now in the di-



TWO UNSYMMETRICALLY LOCATED WINDOWS.

rection from the one to the other, then from the other to the one, and so forth, alternately. This motion of the lymph, however, in this case, is not to be regarded as the kind of motion spoken of in the primitive organ, that is, as molecular motion within the lymph. Rather it is a motion of the whole mass of the lymph, up and down in the figure.

In a cross-section avoiding the windows the cavity with the partition within reappears in another figure. On the left of the figure the partition appears in its undisturbed



THE BENDING OF THE HAIRS ON THE PARTITION.

position, and on the right of the same figure it appears bent down (exaggeratedly, of course, in the drawing). A kind of very delicate membrane (maybe a mass of threads like a brush rather than a membrane) is fastened to one side of the wall and touches the hairs so that their tips adhere to it somewhat firmly. It is immediately clear, then, that the partition can not be pushed up and down by the

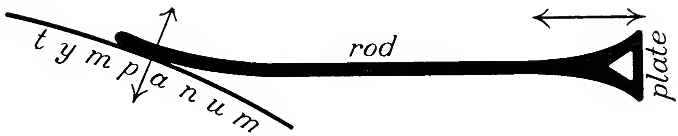
moving lymph without causing a bending of the hairs, which are rooted in the partition and have their tips in the upper, brush-like, membrane.

We thus understand the "second method" of functioning of the Other-One's auditory organ. Again it depends on a bending of the hairs of the sensitive cells. The greater sensitiveness of the organ is secured by doing away with the necessity of the density wave passing thru the substance of the animal's body. Instead, the wave is led thru a passage, or tunnel, as we said, to the two unsymmetrically located windows. There is less loss of energy in the passage thru the tunnel than in the passage thru the body substance, and accordingly this second method of functioning of the organ must be regarded as an improved, less primitive, more developed one.

It is clear that for this second form of functioning much depends on the flexibility of the two windows. These windows should be protected against intruders like small parasites living on the surface of the animal and capable of entering the tunnel. And in animals living in the air, like the Other-One, the windows should be protected also against the drying effect of the outer air. Nature, therefore, has closed the tunnel with a membrane, the "ear drum" or "tympanum." The tympanum happens to be slightly funnel-shaped. But this shape is not very essential. That the protection afforded by the tympanum to the Other-One's "windows" of the inner, lymph-filled cavity is very important, is proved by much clinical experience concerning the results of a breaking of the tympanum.

Would it not occur to you, having the Creator's power, that you might now utilize this drum, created merely for protective purposes, for the transfer of the sound energy directly to one of the windows? The advantage result-

ing would be that the amount of energy usable would no longer be limited by the amount of asymmetry in the location of the two windows relative to the tunnel. The transfer of the energy is easily accomplished by means of any kind of solid object attached both to the drum and to one of the windows. In the birds and lower vertebrates this solid is a simple slender rod, sometimes with a triangular



USE OF THE PROTECTIVE DRUM FOR A SECONDARY PURPOSE.

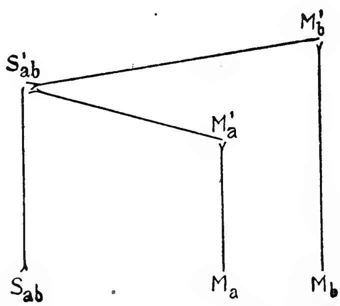
opening as seen in the figure. In the mammals it consists of three little jointed bones, the "auditory ossicles." One of them looks very much like a stirrup and is therefore called the "stirrup." Its plate is attached to one of the windows, the "oval window." The ossicle forming the middle link of the chain is called the "anvil" because it faintly resembles an anvil in shape. The third ossicle, which is attached to the drum, resembles a hammer still more faintly than the second can be said to resemble an anvil. It is called hammer chiefly because a thing acting on an anvil seems to deserve the name "hammer."

Thus there is a "third method" of functioning of the Other-One's auditory organ. It differs from the other two by including the function of the chain of ossicles located in the air-filled cavity of the "middle ear," which is the name given to the space between the drum and the windows. From what we have said it is clear that the functioning of the sense organ does not absolutely depend on the existence of the drum and the ossicles. Indeed, even when, as in a normal condition of the Other-One, they exist free

from all impediments, their significance seems to be the less, the greater the frequency of the sound waves acting on the sense organ. When the frequency is high, and the waves are therefore of small length (a few inches only), and the asymmetry difference of the windows is an appreciable fraction of the wave length, the ossicles are hardly needed. But for the lower tones, where the frequency is small and the wave length great, the mediating action of the drum and the ossicles seems to add much to the efficiency of the organ.

If you now examine the sense organ created, you discover that it might be improved still further.

Think of a fox whose ear is struck at the same time by the whistling of the wind and the cackling of a fowl. If he needs food, he ought to react negatively localizing the high tones of the wind and positively localizing the lower tones of the fowl. Or think of a dog whose ear is struck at the same time by the roaring of a lion and the much higher voice of his master. You cannot fail to notice the advantage which must result to the dog from the ability to perform both reflex responses at the same time, to run away



ONE SENSORY POINT SERVING SEVERAL MOTOR POINTS OR EACH ONE SEPARATELY.

from the lion, but in the direction of his master rather than in any other direction which might also lead away from the lion.

In accordance with what we have already learned it must be emphasized that this ability, in general, by no means requires that both excitations originate in distinct sensory points. They might originate in one point. We have convinced ourselves previously that the neurons, at least some of the neurons of every animal, possess a specific (specifically low) resistance. As a result of it two excitations originating in the same sensory point, say S_{ab} in our figure, may become separated, say at $S^{1}/_{ab}$, and may be conducted, further on, each virtually over its own path, one to M_a, the other to M_b.

But it seems nevertheless necessary, in the case of the auditory excitations, since these depend for their distinctive qualities on the frequency with which the sensitive hair cells are disturbed, that of two kinds of auditory excitations originating during the same time the one must spring from one sensitive cell (or group of such cells) disturbed with one frequency, and the other excitation from another sensitive cell disturbed with another frequency. Why?—Simply because there is no concrete meaning in saying that a body trembles with two or more frequencies of jerks at one time. The total number of jerks during the unit of time is the frequency with which it trembles; and there is only one such total number.

If there must by necessity be during the same time another frequency of trembling causing another excitation, this must be caused to happen in another sensitive cell.

But at some later time the other frequency of trembling may very well happen in the same, first, cell. Each of the sensory points may have—at different times—any one of the thousands of possible auditory excitations aroused within it; it all depends on the frequency with which the sensitive cell happens to be jerked about at the moment.

Fortunately Nature's task of equipping the auditory cells is simplified by the limited need for localization reflex paths. In the eye every sensory point, we remember, has its own localizing reflex path. In the ear there are not thousands, but only two different localizing reflexes, one belonging to all the sensitive cells of the left ear in common, the other to all the sensitive cells of the right ear in common. This opens the way for easily assigning to any one sensory point a large number of reactions among the eight classes of fundamental reflex actions which we distinguished.

Acting as the Creator's deputy, you now want to improve the auditory organ in such a manner that a compound density wave acting on the windows will cause certain sensitive cells (located, we know, in the "partition" of the lymph-filled cavity) to be jerked about as many times as the frequency of the highest component tone, other cells as many times as the frequency of the lower component tone, and other cells with still lesser frequency if there are still further physical components.

All that you have to do in order to bring this about is to lengthen that lymph-filled cavity. You must stretch it, change its shape from that of a sack-like cavity into a kind of tube, at one end of which the windows are located, and stretch, of course, the partition also lengthwise thru the tube. The reason for stretching the cavity and changing it into a tube is no other than that of obliging the density change of the external medium to spread its effect more or less over the partition, that is, over further or fewer sensitive cells, according as the density change of the compound sound wave happens to be vigorous or faint at each moment. In the more primitive, sack-like cavity virtually all the cells are at every moment indiscriminately under the influence of the external density change. Now, in the

tube, at any infinitely small moment, some are and some are not under this influence, and at another moment others are and others are not.

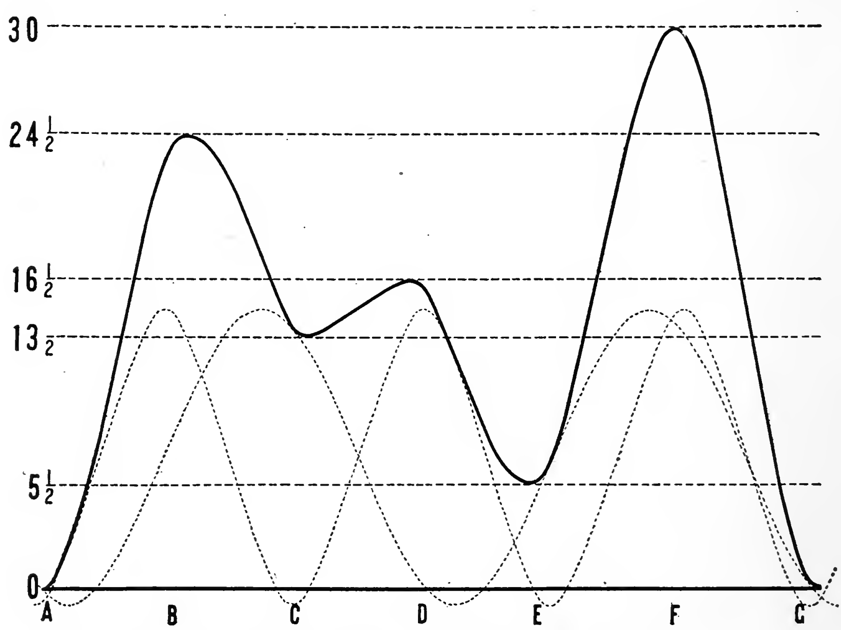
Some fifty years ago curious reasons were believed to have been Nature's purpose in stretching out the cavity and its partition. For example, it was believed that Nature had thus developed the partition into a sort of layer of harp strings or grand piano strings on which the sound wave could then "play by resonance" as you can play on the piano strings, without touching them, if you merely step on the pedal and, having previously raised the lid, sing or speak into the box. The piano then sings or speaks back. Thus the Other-One's "ear," it was said, takes up the sound and speaks, not back, but to the Other-One's nervous system.

The more plausible reason for the stretching of the cavity and partition—simply in order to extend the sensitive surface of the organ in the direction away from the windows, that is, from the nearest possible point of attack—was first given by the French otologist, Pierre Bonnier, to whom belongs the honor of suggesting this idea altho he never showed in detail the consequences for auditory perception of this stretching of the sense organ. We then have here the "fourth method" of functioning of the Other-One's auditory organ.

There are various ways of showing in a graph a compound sound curve. Our figure shows such a curve of density changes in the air produced by two (let us remember "two") musical instruments of which one causes two "waves" while the other causes three during the same time unit, a small fraction of a second.

There are also various ways of showing in a graph the shape which the partition, seen in section lengthwise, as-

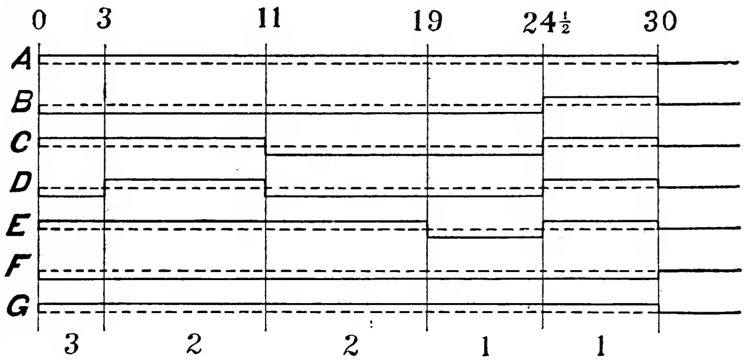
sumes at the moments whenever the sound curve shows a maximum or minimum of air pressure. The next figure gives us one sample graph (reproduced from the writer's "Mechanics of the Inner Ear," U. of Mo., 1907) which corresponds to the sound curve of the preceding figure. The dotted line represents the place where the partition would be found while nothing at all was going on. If the motion of the lymph in the double tube-like cavity is toward the oval window (the stirrup window), the partition yields upwards until it becomes so tightly stretched that it will go no farther up. This limit is of course shown in the figure with great exaggeration. If the motion of the



TWO SERIES OF SOUND WAVES COMPOUNDED.

lymph is toward the other window (the so-called round window) the partition behaves in the same manner downwards.

It is important, however, to keep always in mind that, whenever a reversal occurs, a lowering of the air pressure instead of a rising or vice versa, the piece of the partition which reacts first to the reversal is that near the windows; and only when this piece will yield no further to the onrush of the fluid, will a further piece of the partition yield, always proceeding in this manner from the left to the right, no matter whether the partition goes up or down.



AN APPROXIMATE REPRESENTATION OF WHAT HAPPENS TO THE PARTITION.

This must naturally so occur in accordance with the physical law that every motion occurs with the least possible expenditure of energy both in shifting the masses and in overcoming internal friction. And we remember that for this very purpose of extending the effect to a distance from the windows which is the greater, the greater the pressure change, the cavity and the partition have been stretched out in the direction away from the windows.

Now, at A in the last figure we find in the upper limit an initial piece of the partition—thirty units in length, let us assume. We find this piece in the upper limit because the density change represented in the preceding figure has occurred periodically many times already. We do not consider at all the more complicated changes occurring in the

partition at the very beginning of the sound, since they interest us much less.

From the time A to the time B there is a pressure increase in the air of 24½ units. At the moment B, accordingly, we find an initial piece of the partition 24½ units long in the lower limit.

From B to C the pressure decreases 24½ to 13½, that is, by 11 units. We therefore find at the moment C an initial piece of the partition 11 units long in the upper limit.

From C to D there is a pressure increase from 13½ to 16½, that is, by 3 units. We therefore find at the moment D an initial piece of the partition 3 units long in the lower limit. The piece directly following on the right is drawn as being still in the upper limit in which it was at C. It can hardly have changed its position appreciably, since no force has been acting on it meanwhile. The next piece, following on the right as far as the mark 24½, is drawn as being still in the lower limit in which it was at B. The following piece is still in the upper limit as at the moment A. And the continuation of the partition farther to the right is unchanged since this sound wave is presumed to be not strong enough to affect it.

From D to E there is a pressure decrease of 11 units. Accordingly, 11 units of the partition are sucked up. This upward movement, then, is what happens to the first three; but the eight following (from 3 to 11) are already up. These eight are therefore left where they are, and eight more (from 11 to 19) are sucked up from their lower position at D to an upper position at E. Those pieces of the partition which follow on the right (from the mark 19 to the right) simply remain each in that position in which it was at the moment D. No force has acted on them meanwhile.

From the moment E to the moment F the air pressure increases from 5½ to 30, that is, by 24½ units. Accordingly, so many units of the partition are pushed down,—the initial ones, that is those near the windows, first, the others soon afterwards. First those from the mark zero to the mark 19 are pushed down, then those from the mark 24½ to the mark 30.

From F to G the pressure falls 30 units. Thirty units of the partition are sucked up. At G we find these thirty units therefore in exactly the same position in which we found them at the start, at A.

Let us not forget, now, that this graph shows us only in certain general outlines what goes on in the partition. The finer details of this occurrence have been sacrificed to the need of a first understanding of that which is most essential.

Looking down the "columns," so to speak, of the last figure, we count in each column how many times the sensitive cells of that part of the partition have been jerked down and up. In the initial section we count 3 such jerks, in a following section 2 jerks, and in a farther section of the partition only one jerk in the time unit from A to G.

It is clear, then, that three classes of excitations take their origin from the ear and pass thru the nervous system in those directions where they find favorable conditions of resistance. What at first astonishes us is the fact that not only the excitations "3" and "2," which we expected to find, but also the excitation "1" are present. This, however, is entirely in accordance with the facts if we study the Other-One's auditory perceptions sufficiently in detail. If we sound two tuning forks, the Other-One will generally tell us, provided he has enough training to answer our specific question, that he hears three different tones.

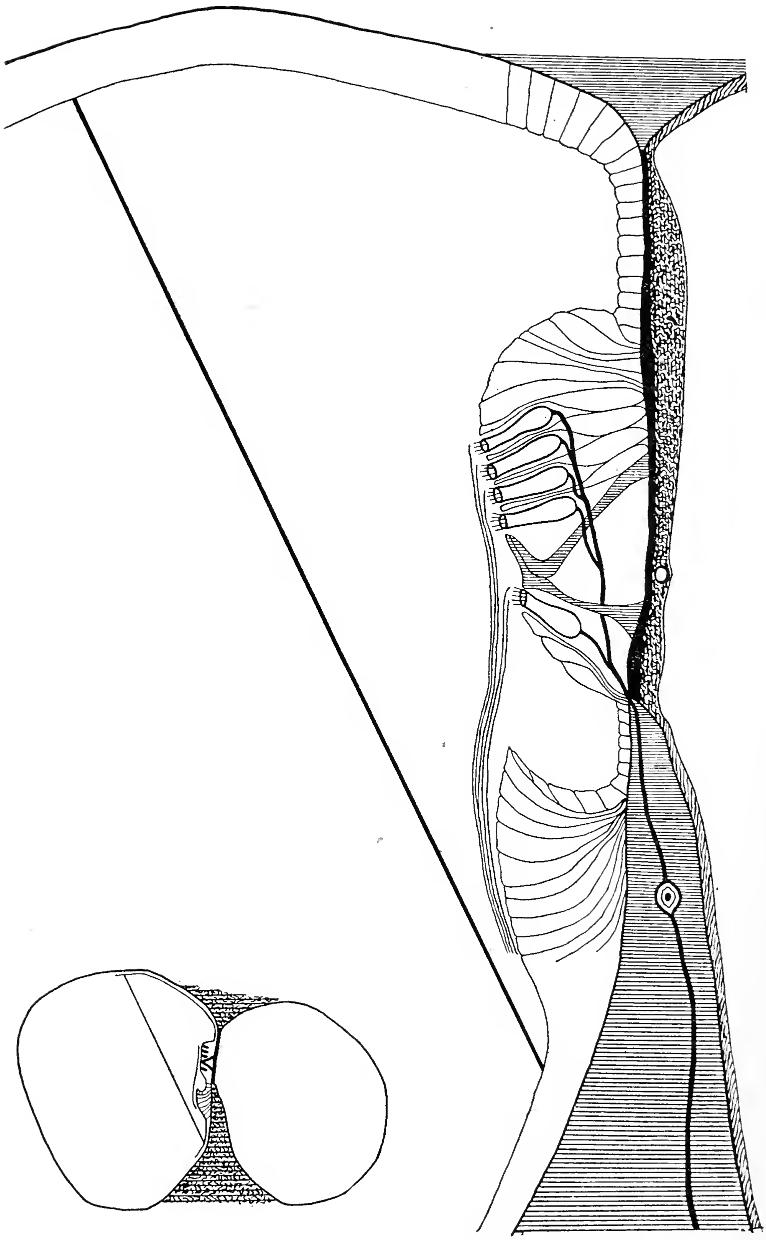
But what is most important is the fact that each of our tone stimuli, "3" and "2," produces its own excitation. If the effect of the sound wave had been confined to the small area of the partition in the primitive cavity, if it had not been spread over the partition lengthened within the tube, the three jerks conspicuous in the sound wave would have resulted in a single corresponding excitation; and that would have been all. Several simultaneous excitations and several simultaneously determined reactions, like the dog's running away from the lion and toward his master, would have been impossible without this lengthening of the sensitive surface.

It will probably be of some interest even to the student who is not interested in the special problems of the function of the sense organs, to mention here a few of the secondary anatomical features which have resulted from the continued lengthening of the tube containing the sensitive surface. First, as the tube lengthened, it coiled up. Some explain this as due to a saving of space. But it is hard to see why the tube could not, on that account, find room in the thick bone of the base of the skull just as readily if it had grown along a straight line. It is a much more plausible argument that, in coiling up, the sensitive surface exposed itself to stimulation by the first mentioned, most primitive method more efficiently than if it had remained straight. Thus a sound wave passing thru the body can act on some part of the "fur lining" no matter in which direction the wave proceeds thru the three dimensions of space. Thus the advantage is regained which was impaired when the "fur lining," as we remember, was taken from the walls of the cavity.

A second anatomical feature which easily arouses the student's interest is the fact that a kind of skeleton, look-

ing in cross section like two pillars falling against each other and forming an arch between the sensitive cells, was introduced when the tube became long. In the birds, in which the tube is not yet very long, these pillars are absent. In our figure of a cross section of the tube in the mammalian auditory organ these pillars are very conspicuous. It is clear that, when the tube is very long, the initial sections of the partition near the windows undergo especially violent pressure changes. Such a skeleton, unnecessary in the birds, becomes then desirable. And in the initial sections it ought to be especially stiff. So it is, for in the initial sections the pillars form a more acute angle than in the parts of the partition farther removed from the windows.

A third feature worth mentioning even in this brief discussion is the membrane which is stretched at a slight distance above that side of the partition on which the sensitive cells are placed. There is, of course, a considerable motion of fluid unavoidably also lengthwise in the double tube. This acts by friction on the partition and might cause damage. On the side of the partition (the lower side in the figure) where there are no sensitive cells, no damage is to be feared. But on the other side special protection is needed and given by the rather big membrane which in the figure appears above, stretching from wall to wall of the tube. In a sense, then, we can give the name of "the partition of the tube" to everything between this upper membrane and the lower surface of the partition as hitherto spoken of. The partition in this new sense is then a kind of hollow wall carrying in its interior the delicate hair cells, their supports, and the ends of the sensory neurons.



THE SENSORY CELLS CROWNED WITH LITTLE HAIRS AND THE SUPPORTING PILLARS IN THE PARTITION.—TO THE LEFT ABOVE THE ENTIRE AUDITORY TUBE IN CROSS-SECTION.

Let us once more state the four different methods of functioning of the auditory organ, beginning with the most primitive method and ending with the most developed one.

But let us keep in mind, now, that all these methods of functioning are possible and actually occur in the same auditory organ, the highly developed anatomical structure called the Other-One's "ear"; that the possibility and actual occurrence of the most highly developed functioning does not exclude, in the very same ear, the possibility and actual simultaneous occurrence of any of the more primitive forms of functioning.

1. The Other-One's ear can function like a cavity lined with hair cells and exposed to any sound wave passing in any direction thru his body.

2. The Other-One's ear can function like a cavity in which the hair cells are placed on a floating partition, there being a "window" on each side of the partition, and a tunnel leading the sound more directly to one window than to the other.

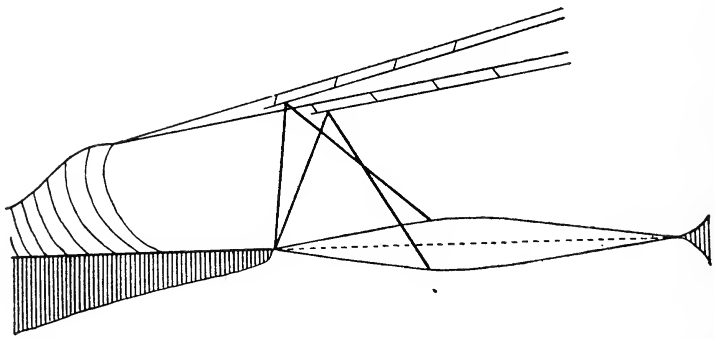
3. The Other-One's ear can function like (2) with the difference that the sound waves are transported by means of a solid connection from a protective "drum" in the tunnel to one of the windows.

4. The Other-One's ear can function either like (2) or like (3) with the difference that the up or down motion produced in the partition is farther or less far extended over the greatly lengthened cavity and partition, according as each positive or negative change in the air pressure is more or less intensive.

To the extent that pathological conditions interfere with any of these forms of functioning, the Other-One has to rely, and as a rule fortunately still can rely, on the others.

We stated that Nature at the start equipped the auditory organ of animals with hairs, exposing them in such a manner that the slightest pressure changes in the medium surrounding the animal would effect a bending of these hairs. It has been shown some years ago by Emile ter

Kuile that in this most lately developed fourth form of functioning of the organ the hairs of the sensitive cells are bent back and forth. Our diagram shows these hairs indicated only by four short lines between two parallels. The upper parallel represents the fine brush-like membrane previously mentioned as touching the tips of the hairs. The lower parallel represents the surface formed by the sensitive cells in which these hairs are rooted. The sensitive



HOW THE HAIRS OF THE HAIR CELLS ARE BENT IN THE HUMAN EAR.

cells themselves are not drawn in this diagram. But the "skeleton" supporting them, that is, the triangle formed by the two pillars, is shown, having its vertex, of course, in the lower one of the two parallels spoken of. The diagram shows how the hairs must bend when the two parallels slide over each other in consequence of the partition being jerked out of one of its extreme positions into the other. It seems remarkable that in spite of all the changes which the anatomy of the auditory organ has undergone in evolution, the bending of the hairs still seems to be the most essential factor in stimulation.

Having obtained, now, an elementary understanding of the functioning of that sense organ whose main purpose is the receiving of signals, we naturally turn in the next chapter to a discussion of the "vocal" organ by means of which the Other-One ordinarily transmits his signals.

CHAPTER XIV

THE OTHER-ONE'S TALKING MACHINERY.

An acoustic signal is a periodic change of density in the air. In order to understand clearly the Other-One's signaling apparatus we must first of all impress upon ourselves the fact that such density changes in the air can be produced either directly in the air itself, by friction suffered by a stream of air, or indirectly by a vibrating solid which beats the air periodically. Density changes of the latter origin are not only very regular (owing to the regularity of the vibration of such a solid), but also rather strong. Density changes caused directly in the air by friction (for example, the breathing noise) are generally both weak and irregular in a physical sense.

But both kinds of density changes can be greatly strengthened and can also, if they were before irregular, aperiodic, be made regular, periodic, by the mediation of an air resonator. An air resonator is nothing but a volume of air almost entirely enclosed within a solid container, but communicating with the outer air thru an opening in the container. The smaller the enclosed volume of air, the greater the frequency of its proper density changes, or, as we say, the higher the tone. And the larger the opening, the higher the tone. However, the size of the opening must have a certain reasonable relation to the volume, or the resonance will be very weak.

All these facts mentioned can be easily illustrated with ordinary musical instruments of the wood-wind type. In a flute the density changes in the air are caused directly by

the friction of a stream of air blown against a sharp edge; and the air volume in the flute resonates, that is, makes the density changes regular and strong. In an oboe or clarinet a reed (that is, a solid body) is caused to vibrate by blowing against it; and again the air volume in the instrument resonates, causing the density changes to be still more regular and stronger than they would be if depending merely on the manner of the vibration of the reed.

We have mentioned in a previous chapter that animals are equipped with a class of reflexes which enable them to use their breathing apparatus, the lungs, also as a blowing apparatus for causing periodic density changes of high frequency in the air. The muscles serving these reflexes are the diaphragm and the muscles of the chest acting on the ribs.

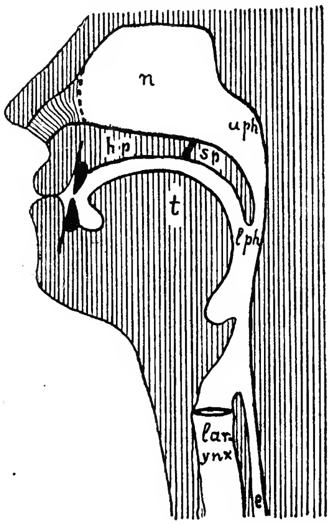
The blowing apparatus is thus comparatively simple, as is to be expected. The friction apparatus, which we have to discuss next, is more complex. And the resonating apparatus, which will be discussed last, is most complex.

Our figure shows in its most essential features the passages thru which, during the Other-One's vocal activity, the air has to take its path in or out. (There are, however, but few languages on earth in which sounds for signaling are produced by drawing the air in.) If the Other-One does not anywhere in these passages thru special muscular action obstruct the motion of the air, the friction is so slight that no sound is produced which deserves to be called a speech sound (as in ordinary breathing).

Obstruction can be caused easily in the larynx by stretching the so-called vocal cords so that they leave less room between them. Obstruction can, secondly, be caused in many different ways, as appears clearly from the figure, by the muscles of the upper lip, the lower lip, the lower jaw,

the tongue, and the soft palate. For simplicity's sake we may call the totality of all these latter organs "the mouth."

But there is one great difference between causing the necessary friction in the larynx and causing it anywhere in the mouth. It is the same difference which exists between the oboe and the flute.



THE MOUTH AND THE LARYNX FORMING THE HUMAN "OBOE."

The parts constituting the mouth are not easily capable of vibrating, because they are virtually never, normally, under that tension which is physically necessary in order that a solid may vibrate. The motion of the air may be obstructed, for example, by putting the lips together. But the lips do not then vibrate. The bugler may force them to vibrate, but only by pressing the mouthpiece of his bugle against them and thus giving them an artificial tension. Normally their tension is too weak for vibration. Or the motion of the air, to give another example, may be obstructed by placing the tongue against the upper teeth or against the hard palate. There may then be much friction, but neither the teeth nor the palate can vibrate under such

conditions. And if the tongue should vibrate, it does it with such a small frequency as to cause no sound of its own, but to add merely some roughness to a sound which originates elsewhere, as "r" and "l." Therefore the friction produced anywhere in the mouth is comparable to the friction in blowing a flute. There is no solid body which is blown against and which in consequence vibrates.

But when the cushions of which the vocal cords form the most advanced edges narrow the opening in the larynx, they do that thru the very tension of the vocal cords. The case is then quite similar to that of the oboe. There the reed, which obstructs the air motion, vibrates when air is forced thru. Here the stretched vocal cords vibrate when air is forced thru.

From what we have previously said it is clear, then, that whenever the air is obstructed in the mouth, the resulting sound is relatively weak; and whenever the air is obstructed in the larynx, the resulting sound is relatively strong. The sounds of the first class are therefore called voiceless sounds and those of the second class voiced sounds. In more popular terminology, the production of the former (voiceless) sounds may be called whispering, that of the latter (voiced sounds) singing or ordinary loud speech.

The existence of a great obstruction in the mouth, as in pronouncing "s," precludes a sufficiently strong fall of the air pressure, on the passage from below the vocal cords up to above the vocal cords, to bring about vibration of the cords. But if the air is only moderately obstructed in the mouth, a certain amount of vibration of the vocal cords is simultaneously possible. We then have "voiced" speech sounds like "z, d, b, g, v, w." With a greater obstruction in the mouth and the then unavoidable failure of the vocal cords to vibrate, these sounds become the "voiceless" speech sounds "s, t, p, k, f, wh."

It is but natural, then, that in whispering, if we define this as voiceless speech, the sounds "z, d, b, g, v, w" are impossible. They are indistinguishable from "s, t, p, k, f, wh." Ask the Other-One to whisper strongly, but really to whisper, "zeal" and "veal," and they will sound like "seal" and "feel." However, it must be emphasized here as nearly everywhere in phonetic discussions, that all distinctions are relative, that there are intermediate steps between the extreme of whispering and the extreme of voiced speech. In the so-called stage-whisper, for example, the distinction is possible.

Of course, when we said that somewhere the passage of the air must be obstructed in order to cause "by friction" a sound, we did not wish to give the impression that this friction was one perfectly simple physical process incapable of variations. The friction may be a steady process, as in pronouncing "s" or "sh;" or it may deserve the name, rather than that of friction, of an explosion or sometimes the reverse, a sudden choking, as in pronouncing "k" or "p" in the beginning or end of a syllable; or it may be something between explosion and plain friction, like the repeated weak explosions of "r" or "l," which, on account of their repetition, we do not recognize as explosions.

Thus far we have been speaking of the sound only as it results exclusively from the friction which is caused by obstructing the passage of the air, forcefully expelled from the lungs,—with or without the aid of a vibrating solid body, that is, the vocal cords. We have not yet discussed the factor of resonance.

But the variations of resonance are that very factor which makes "articulated" speech what it is. Without the manifold variations of resonance the Other-One would possess virtually only (1) friction noises (a kind of whispering, as we called it, but not "articulated" whispering) com-

parable to the noise of steam escaping with more or less force from a boiler and (2) musical tones comparable to the song of birds. And he would use the one or the other according to circumstances, but hardly both simultaneously.

A glance at our figure shows how easily a great variety of resonating air volumes can be formed, and—what is especially important—not only a variety from moment to moment, but a variety of several air volumes at the same moment, a small volume here, a large volume there, each having its proper tone. Thus we understand the significance of the lengthening of the Other-One's auditory organ into a tube which we discussed in the preceding chapter, whereby different sensitive cells are enabled at the same time to be excited in different excitations.

The tongue (t, in the figure) can be pushed forward toward the teeth or backward toward the soft palate (sp). It can be pushed up toward the hard palate (hp) or down, leaving little or much space between itself and the palate. The lower jaw can be lowered, enlarging in any desired manner the mouth cavity and enlarging also the opening between the teeth. The lips can be arranged so that the mouth cavity is prolonged forward. The lips can also make the opening of the mouth of any desired size. The soft palate can be pushed backwards in order to close the communication between the upper and lower pharynx (uph and lph) and exclude thus completely the nasal cavity (n) from acting as a resonator. On the other hand, the tongue can so well fill the mouth cavity that the pharynx and the nasal cavity alone serve as resonators.

When the Other-One sings like a bird, that is, without pronouncing at the same time words, he forms, more or less skilfully, one large resonating cavity of all those cavities at his service. This one resonating cavity is then merely adjusted in accordance with the frequency of the

vibrations of the vocal cords in the larynx (in front of the esophagus, e, in the figure). But in speech he forms numerous resonating cavities at the same time and locates the obstruction (or obstructions) wherever the resulting friction will be near enough to the cavities to make them properly resonate. It is clear, of course, that thus similar sounds or even identical sounds (that is, compound sounds consisting of the same components) can frequently be produced by more arrangements within the vocal organs than one. The larger one of two simultaneous cavities may be located here and the smaller one there, or the smaller one here and the larger cavity there. The total sound might be about the same. It is important to understand this in order to avoid the needless differences of opinion which arise sometimes in phonetics as to whether a certain speech sound must be produced in one manner or in another. It might be produced in either manner equally well.

To these several sounds caused by friction and resonance of the air cavities may then be added or may not be added the larynx tone. If the larynx tone is not added, we speak of articulated ("joined together") whispering. If it is added, but is not very strong and varies much, we hear the Other-One's normal loud speech. If the added larynx tone is overstrong, but still varies much, we call it shouting. If the added larynx tone is very strong, but held at constant pitch (vibration frequency) for a little while, to assume another constant pitch for a little while, and another constant pitch, we hear the singer's performance, as in an opera or whenever the Other-One sings a song.

What, now, is the difference between consonants and vowels? This is, perhaps, the first classification we learn in our earliest school life to make of different speech sounds. And yet it is a rather insignificant and almost

superfluous classification. We learn that vowels are those speech sounds which may form a syllable (a syllable is that group of sound qualities which occurs between two sound minimums and has only one maximum) while occurring alone and unaccompanied by consonants, and that consonants ("by-sounds" in the sense of accompanying sounds) are those sounds which never form a syllable while occurring alone, but must occur "by" a vowel. However, it is purely accidental that we do not in the English language have, for example, a syllable consisting purely of the voiceless sound "sh." There are other languages which have such syllables, and "sh" would then have to be called a vowel. This shows clearly enough the scientific irrelevancy of the distinction between English consonants and vowels.

Psychologically interesting are all those cases where in speech the pronunciation of a sound is modified by the occurrence of another one just before or just after. It is but natural that, for example, the first syllable should be pronounced differently in the two words "do" and "doing," that the Other-One should in the latter case make the resonating cavities for the two syllables succeeding each other as much alike as this is possible without risk of being misunderstood. This is so justifiable an economy that virtually nobody fails to develop his speech habits in accordance with it. In the study of languages we discover innumerable examples of speech economy which have become so conspicuous that they have found expression even in spelling.

Lazy people, of course, will economize without much attention to the question whether the Other-One's understanding becomes impaired thereby or not. It is all right to say "cupmsaucer" if the Other-One's native language is English and if he can almost guess what we are saying. But if he is a foreigner and not perfectly accustomed to English, and we want him to understand us, we should rather pronounce "cup—and—saucer."

But even lazy people sometimes get excited and may then expel the air from the lungs so forcefully that a mouth friction sound is heard in a word which does not possess the sound, but which word the excited speaker wishes to emphasize, whereas in another word which he does not wish to emphasize he fails to produce, thru his laziness, the very friction sound which rightly belongs there. For example: Barber—The cholera is in the hair. Customer—Then you ought to be careful about the brushes you use. Barber—I didn't mean the air of the ead, but the hair of the hatmosphere.

When the Other-One is excited because you have told him that you are going to punish him, and he asks "Why?" he will probably let the vowel be preceded by the strong mouth friction sound "wh."—But if you ask him if he wears a fur coat in summer, and he smilingly replies "Why, nobody does that," he will probably pronounce the first sound as "w," with very little air friction in the mouth.

The general features of speech in relation to personality have been well described by the Danish linguist Jespersen in the following brief paragraphs:

"Every one has his own speech, differing from every other person's speech. This is true with respect to his vocabulary, his idioms, his syntax and his grammar; but also with respect to his pronunciation. When we recognize a person by his 'voice,' that last term is not taken in the narrower meaning of 'larynx sound,' but in the broader meaning of his pronunciation as depending also on his palate, tongue, teeth, lips, the elasticity of his cheeks, and even the muscular equipment of his breathing apparatus.

"He who dissimulates his speech, pushes forward his lips, lowers his jaw, flattens his tongue, and so forth.

"Very characteristic for a person's speech is also his tempo of speaking and the greater or lesser precision in

the execution of the movements of his vocal organs, on which the clarity, comprehensibility and beauty—or the opposite—of his speech depend.

"Tho every one has his individual speech, that speech varies from time to time according to the situations in which he finds himself, just as his facial expression changes from time to time.

"In general it can be said that those who speak a common language have something common in their pronunciation. Consequently it is sometimes possible, when one hears spoken words from such a distance that the separate words are not recognizable, to tell nevertheless what language it is.

"Thus, too, it is frequently possible to tell of what country or part of a country a person is a native, even tho he speaks a foreign language, since he may not have freed himself from the characteristic peculiarities of his native tongue, but may unintentionally use them in the other language, speaking—as the popular phrase goes—with a 'foreign accent.' In reality this is not alone a matter of accentuation, or perhaps least of all a matter of accentuation, but rather a matter of moving his speech organs in the old accustomed way.

"There is a kind of harmony among the motions of the vocal organs producing the several sounds of a particular language. For example, that language which pronounces 't' with the tip of the tongue far back in the mouth, most likely pronounces also 'd' and 'n' with the tongue thus withdrawn. And if 'b' is strongly voiced, one may be almost sure that 'd' and 'g' are also strongly voiced. Thus, in certain cases, one may learn to imitate the pronunciation of a foreign language beyond the possibility of a distinction by merely flattening quite generally the tongue, or pushing it forward or withdrawing it, by retarding all lip movements, and so forth.

"In this sense it may be asserted that each language has its 'base of operations' in a particular region of the mouth, or that it has its particular 'pose' of the mouth organs. And just as the pronunciation of each individual represents and expresses the peculiarities of his personality, so the 'mouth pose' of each language has a definite relation to the national character. Nevertheless, no more than such a national character is the 'mouth pose' of a language easily and clearly describable in terms of scientific value."

It is customary to say that a child learns the language of his parents "by imitation." It is more correct to say that he learns it by imitative (reflex as well as habitual) actions.

According to the usage of language any action deserves to be called imitative (or "an imitation") which repeats the stimulus, or at least produces something very much like that stimulus which gave rise to this action.

We have agreed in this book to mean by a reflex or by an instinctive action about the same thing, that is, the functioning of one definite nervous path of the "short" and inherited variety, a path which serves to place a perfectly definite motor point at the disposal of a perfectly definite sensory point. The motor "point" may be a "group" of muscles, and the sensory "point" may be a "group" of sensitive cells, and then we should prefer the phrase "instinctive action" to the word "reflex." But this distinction referring to complexity or simplicity is a minor matter and really does not concern us at this moment.

But while the functioning of a definite nervous path (that is, a reflex or instinctive action) can be called a "right-sided" action, if it occurs on the right side, or an "imitative" action, if it repeats the stimulus, never can the abstract noun "right-sidedness" or the abstract noun "imitation" be called a reflex or instinctive action. An action

is something concrete. Its functional basis in the nervous system is likewise something concrete. An abstraction can be used as the name of a concrete thing, but never can an abstraction be spoken of under the term standing for something concrete,—unless we are tired of logic and try our luck by playing with intentionally introduced confusions. As we said in a previous chapter that "right-sidedness is not in itself a reflex, but a peculiarity of some reflexes," so we must say here that imitativeness is not in itself a reflex, but a peculiarity of certain reflexes. Saying that imitation is an instinctive action would be like saying "creation is a fish" because a codfish is a creation.

If we wish to express ourselves clearly, we shall be the clearer, the more frequently we speak concretely of this and of that special "imitative action" (which may be native or acquired) and the less frequently we speak generalizingly of "imitation." There is absolutely nothing in the substances or the functions of the nervous system which can in any way be said to be correlative with the generalization (or abstraction) "imitation."

Since speech imitating actions have led us to this discussion, we should, in order to make the matter still clearer, ask what kinds of imitative actions other than speech imitating actions we find in the Other-One's life. In speech the Other-One reacts to sound and produces sound. This is auditory imitation.

If a smell causes the Other-One to act so that a similar smell results, this is olfactory imitation. He does that, perhaps, as a perfumer's apprentice, journeyman or master perfumer. Fortunately nobody has given vent to his enthusiasm for the abstract terms "instinct" and "imitation" far enough to explain the perfumer's actions as due to his "instinct of imitation."

If the Other-One reacts to a taste so that a similar taste results, that is gustatory imitation. It is a good guess, in that case, that his vocation is that of a cook.

If the Other-One reacts to a kinesthetic excitation in such a manner that he reproduces the kinesthetic excitation, that then is kinesthetic imitation. Very likely his vocation is that of a circus athlete.

It is perfectly clear in the last as in the preceding cases that the imitation results from having obtained the knowledge that imitative actions are often useful, are often the basis of success,—success in a business, in a trade, in a skilful athletic performance, in what not. Nobody calls such a knowledge an instinct.

Nobody imitates a smell instinctively. Does anybody imitate a kinesthetic excitation instinctively?

In an earlier chapter we have already had occasion to mention that many special circular reactions are inherited and may usually result from the kinesthetic excitation, resulting from one action, causing another action. If this kinesthetic excitation causes the same action from which it resulted, we have kinesthetic imitation. Does anybody inherit any kinesthetic imitative action?

One might think that the inheritance of kinesthetic imitative actions is almost self-evident from the fact that the sensory neurons of muscles and the motor neurons of the same muscles naturally run together in a single bundle, a nerve. But that is as accidental as running water pipes, gas pipes, sewer pipes, electric wires, and so forth together in the same tunnel under a street or under a river. Within the central nervous system they separate and do not necessarily form "short paths." They form "reflex arches" only where the functional needs of the organism in evolution unite them, as in the case of all other sensory and motor neurons.

As a matter of fact there seems to be very little inherited kinesthetic imitation; maybe no more than olfactory and gustatory imitation, that is, none at all. We remember the case of the child learning to pile up blocks. There is imitation in so far as the child seems to imitate a model (a block standing) by creating a thing like it, only bigger (one block upon another). But the stimulation is visual, not kinesthetic. And the imitation is at the start purely accidental, since the effective reflex, as we remember, is not in that case an imitative reflex, but is simply the visual localizing reflex. The child, with his hand already grasping a block, localizes another block by sight, and then drops his block on that location.

Indeed, if a considerable amount of kinesthetic imitation were inherited, it would greatly retard the acquisition of useful habits of reaction. For example, the child, instead of learning how to build a house of blocks, would continue, thru the influence of such imitative actions, to move his hands up and down in the same manner without being influenced by the fact that blocks other than the one in his hand are lying about. Kinesthetic imitative actions, if inherited, would reduce man's biological significance in the world to something like that of mechanical toys in a child's world, capable only of performing the same jump in endless repetition.

Does anybody imitate a visual stimulation instinctively? There seems to be little evidence of special inherited reflexes imitating visual stimulations. Neither do the earliest learned movements seem to depend on visual imitation nor do the earliest imitative movements seem to be of the inherited type. The baby learns to creep, but—not by imitation. He learns to stand up, but—not by imitation. He learns to walk, but—not by imitation.

It is only after he has acquired these skilful movements of his hands and feet, that visual imitative actions become conspicuous. Then only we observe that the little child, already able to walk, joins us when we are standing with our back against the wall and takes his place at our side, leaning his back likewise against the wall. Then only, after a year of experience in hand movements without any visual imitative actions whatsoever, does he begin to wave his hands in imitation of ours, to put on his hat when we put our hat on. Then he places an open book on the music stand of the piano before he strikes the keys with his little fingers, because he has seen us open our music before striking the keys with our fingers. In all these early imitative actions there is no more evidence of heredity being especially responsible for the imitativeness than there is in the actions of the perfumer. As the smell imitating perfumer may nevertheless fail in his business (if we regard such failure as some evidence against the existence of reflexes), so the sight imitating child may fail in his business, in playing the piano, for example, in spite of his wonderful imitation. Summing up, then: there is scarcely any inherited visual imitation.

That leaves us still more interested in the question how much auditory imitation the Other-One has inherited. There is this to be said, first, that without imitating sounds, the Other-One would surely fail in his business of living a human life. Auditory imitation is so essential that we almost expect Nature to have made some provision for it by equipping the Other-One with special reflexes. The sound producing reflexes belong, we have said, to the signaling reflexes. Nature has equipped animals also with reflexes of responding to signals; but the responses to signals are not necessarily imitative actions, as we have seen in many examples. Generally the reflex response to a signal is not

an imitative action. But it seems that to a certain extent Nature has equipped the Other-One with reflex responses to auditory signals which repeat with some accuracy the auditory stimulation.

What is perhaps most remarkable about auditory imitation is the fact that it appears earlier than all other (no matter what their origin) imitations; and that it grows weaker as the individual grows older, whereas all other imitations seem to grow stronger with advancing age. Auditory imitation begins with imitative reflexes, and hardly develops into imitative habits (altho it develops into definite speech habits) but rather dies out. All other imitations (think of making a fist before your enemy) develop from various non-imitating reflexes accidentally as imitative habits and grow stronger and stronger because the imitativeness is found to serve a purpose. Auditory imitativeness has its maximum during the second year of life. Visual imitativeness is very conspicuous only about a year later and perhaps does not reach a maximum until old age.

The infant imitates reflexly the speech sounds which are produced by others in his presence or by himself. The eight or ten year old child has almost ceased to imitate speech sounds. How slight the tendency to imitate speech has become in grown people, all those know from experience, to their regret, who have ever learned or taught a foreign language. Grown people will do a hundred other things rather that repeat over and over again a phrase just heard as small children do,—the secret of children's rapid success. It is quite natural, however, that auditory imitation should be found so strong during the second and even a few of the following years and so weak later. The child must learn to speak early in life. And he learns by imitating. When this learning of speech is once accomplished.

imitative actions are no longer necessary. Aside from learning speech in early childhood, auditory imitative actions have no biological value of their own.

With visual imitation the case is quite different. It is true that all thru life a good many skilful movements are learned by visual (tho not reflex) imitative actions. However, the visual imitative action itself, aside from all learning, has an enormous biological value all thru life, in old age no less than in middle age and infancy. When we see a crowd gather in the street, we immediately (by habit) run to the spot ourselves,—not because we still have to learn how to run to a point seen, but because we have discovered that it is of immense value for our individual and our social life interests to do at any time as we see other people do, exceptions notwithstanding.

Summing up, then, we may say that auditory imitative actions are virtually the only class of imitative reactions which are inherited and for whose inheritance there is some need; that even here one must not have an exaggerated idea of the exactness of the imitation resulting from the reflex equipment, since the reflex amounts to hardly more than responding to the signaling reflex of another person by a rather vague signaling reflex of one's own, producing varying sounds perhaps at random more frequently than imitatingly (as a dog responds to another's barking by its own barking, but only by chance imitatingly); and that these auditory imitative reflexes become so completely replaced by sound producing habits that after ten years virtually nothing is left of the original value and strength of these imitative reflexes.

What we have said in an earlier chapter about "serial activity" as a special kind of concerted action finds its most important illustration in speech. All speech is concerted action, and among the various kinds of concertedness the

particular sequence of the sounds is obviously of especially great importance. Get ready to say "ga" but stop just before the "g" explosion. Then do the same for the syllable "goo." You notice a great difference of position of the mouth organs and of tension of the various muscles altho the first sound is supposed to be the same. The muscles are clearly innervated and ready at once to produce both sounds, consonant and vowel. Which sound precedes in actual production seems to depend, as in our discussion of serial activity in a previous chapter, on the relative intensity of the nervous flux going to the one and the other group of muscles.

It is possible—indeed probable—that in the pronunciation of such words as "god" and "dog" there is no difference at all in the temporal order of the nervous activities involved, but a mere distribution difference of the resistances of the nervous branches serving simultaneously as conductors, to the effect that, in the one case, the muscular "g" tension is stronger than, and thus becomes outwardly effective before, the "d" tension, and in the other case the reverse,—the "o" tension being of intermediate intensity in either case. This condition of relative resistances in each special case is, of course, habit in the particular language, and not inherited.

But naturally, the statement of the last two paragraphs does not deny that kinesthetic excitations may also play a certain role in bringing about particular sound sequences. Kinesthetic excitations are especially likely to be of an important service in determining the proper sequence of the sounds in very long words and whole phrases and sentences. The greater the temporal complexity of the sound, the less self-sufficient for the temporal order can be the manner of distribution of a nervous flux having a single source.

Before leaving speech the peculiar relation between the localizing and the sound signaling reflexes should be pointed out. In discussing the localizing reflex we mentioned that the "most movable" part of the body in each case is the one which performs the localizing movement. Usually this is, of course, an arm. During the second half of the first year this reflex begins to assume the particular form in which not only the arm is stretched out in the service of the localizing reflex, but the index finger too (but not the other fingers). Now, this is about the same time when the first articulated sounds (usual guttural and dental—ga and da) are reflexly produced by the baby. But the act of stretching the index finger, that is, pointing, is accompanied by a dental rather than a guttural sound—the baby pointing and saying "dadada."

We recall here the interesting fact that in all Germanic languages the demonstrative pronouns begin with a dental sound. This does not seem to be altogether fortuitous. Try yourself to accompany a pointing (localizing) movement by a dental or a guttural sound. The latter seems less natural, less easy.

The explanation is probably a mere subdivision of the explanation of a more general fact,—the fact that gestures, especially those of the right hand, are likely to accompany speech, in adults as well as in the young.

For nearly a century it has been known that the left hemisphere of the normal human brain functions in certain cases in preference to the right hemisphere. The connections of the left hemisphere with the muscles of the right half of the body and also with all the speech organs are closer than those of the right hemisphere. A nervous current, therefore, which takes mainly the road to the speech organs and partly also to other muscles, finds less resistance to the muscles of the right arm than toward the

muscles of the left arm. In order to go to the left arm, it first has to go from the left to the other hemisphere. Thus its path becomes lengthened and of increased resistance.

It is natural, therefore, that gestures accompanying speech must be gestures of the right rather than of the left arm.

The case of the dental or the guttural sound fitting better together with the pointing movement, seems to be capable of a similar explanation. A sound which is produced by friction in the front part of the mouth seems to depend within the nerve centers on neurons belonging to and being found among that group of neurons which serves the extremities of the body, like the pointing finger. The muscles of the throat, belonging to a different, an internal group of muscles, are quite likely to be served within the nerve centers chiefly by neurons which belong to and are found among groups of neurons which do not serve frequently the extremities of the body, like the pointing finger. A nervous current is, then, more likely to call forth both a dental sound and the pointing of the index finger than a guttural sound and the pointing of the index finger. That is, this nervous current, when we measure the resistance starting from a certain nerve center. is found to travel over a longer and therefore more resistant path in the direction of the muscles back in the mouth than in the direction of the muscles in the front part of the mouth.

Why movements of the speech organs are likely to be accompanied by gestures at all, of any kind, is a question which we shall hardly raise after having emphasized thruout this book that every nervous current, even when coming from a single source, is widely distributed thru the nervous system, and that any main activity is likely to be accompanied by secondary—and generally, by the spectator,

overlooked—activities. But the question may still be worth raising in this connection why some nationalities gesticulate more than others.

Some languages, especially the English, habitually put an enormous vigor into the enunciation of one definite sound of each word or sentence. The English language, that is, is a strongly accented language. According to the law of nervous deflection we expect, then, that the strong nervous flux leading to the enunciation of the accented sound should interfere more or less with the execution of such secondary actions as hand gestures. This is a plausible explanation of the absence, or at least remarkable infrequency, of gesticulation in speakers using the English language. In the French language, on the other hand, there is no accent worth mentioning. The reflex gestures of the speaker are therefore fully preserved. Accent in speech is thus a substitute for gesture.

This explanation seems more generally applicable than the popular one assuming racial differences of temperament as the exclusive cause of the difference in question. Maybe there are some such racial differences. But taking into consideration the origin of the two peoples, such a difference of "temperament" would remain ethnologically rather mysterious.

CHAPTER XV

Rhythm: Motions Grouped and Thus Repeated.

Who has not had many experiences like the following: You are sitting at the open window thru which the regularly occurring puffs of a distant steam engine reach your ear. You see the Other-One sitting in another part of the same room. Suddenly you observe that he beats the time of the engine puffs, tapping with his finger on the table, or maybe with his foot on the floor. But that is not all. Indeed, that would not be at all remarkable. Why should not each of many regularly repeated auditory stimuli call forth an habitual motion, regularly repeated, of the Other-One's limb?

But you observe that the Other-One's tapping movements are not all equal. They seem to consist of groups of six, or of groups of three, according as you make finer or less fine distinctions.

One of the six strokes appears to be especially vigorous and also to occupy a little more time than each of the other five strokes. It is executed more from the shoulder joint than the others. The two strokes following are executed with a much weaker movement of the hand. In them the upper arm at the shoulder joint takes hardly any part. The motion occurs from the elbow joint rather, or even merely from the wrist. The total time occupied by these two strokes is slightly less what you would expect,—slightly less than double the time of that vigorous stroke. That is, however, natural, since a long pendulum generally has a longer period than a short pendulum, and the vigorous

stroke is a sort of pendulum motion of the whole arm, the weaker strokes only of the lower part of the arm.

In our example, the fourth stroke (the first of the second group, if we prefer) is comparable to the first altho possibly it has the characters of vigor and length in a less pronounced degree. The fifth and sixth are comparable to the second and third.

If you recognize a difference between the first and the fourth stroke, you call what you observe a perception on the part of the Other-One of a six-stroke rhythm. If you fail to recognize this difference, you call it a perception of a three-stroke rhythm. But what do you mean by rhythm?

So much is clear that you do not mean by "rhythm," in the particular sense in which you use this term here, merely that the Other-One does something repeatedly. If that were the case, you could include the Other-One's heart beat in a discussion of "rhythm." But then the very reason for devoting to rhythm a special chapter of a psychological text-book would have disappeared. Then, indeed, you would use the term "rhythm" merely as an (absolutely superfluous) synonym of the term for regularly repeated events on which mathematical science has long agreed, that is, the term "periodicity."

We mean here by "rhythm" that the Other-One groups his motions by putting a special vigor, length, or perhaps still another property, every now and then, regularly, into one of these repeated motions. It is not really essential either that these motions are performed in succession by different muscles, or even different limbs, or exactly the same limb, the same muscle. You might observe that the engine puffs stimulate the Other-One to tap with one finger, using for each motion exactly the same muscles, that is, neither more nor fewer nor other muscles, merely a more vigorous contraction for the "accented" stroke of the group of strokes. That is one of the extremes.

Or you might observe that the engine puffs stimulate the Other-One, while he is standing, to raise his whole left leg and let it fall heavily upon the floor, and to tap then gently once with the index finger of his right hand and once with the index finger of his left upon the table. That is another extreme in the muscular activity. And there are also extremes in the stimulation as we shall see presently.

When instead of the regularly repeated, but unaccented engine puffs the sounds of an orchestra playing a waltz are the effective stimulation in the case, that also is a kind of extreme in so far as the stimulating orchestra marks the accents. On the other hand, you may observe that the Other-One engages in the same kind of remarkable activity when there is absolutely no accentuation or grouping or even repetition in the stimulation. For example, the Other-One may be standing at the window and looking out while a beautiful young lady, his partner in a waltz at yesterday's ball, passes on the street. The sight of that lady is the stimulus. That is the other extreme in the sense of a total absence of even repetition, not to mention grouping, of stimuli.

In all these cases differing in muscular activity and in stimulation you speak of "rhythm." But the most remarkable case among them is the case where the sight of the lady is followed by a gentle tapping of the lone finger on the table, first a little stronger, then twice a little more softly, and so forth. In this combination of extreme conditions, with the peculiarities of the stimulation and of the reaction apparently entirely unrelated, incommensurable, the very problem of "rhythm" formulates itself in your thought: What is it that the Other-One's nervous system possesses which conditions such a strange mode of reaction, repeating grouped motions when there is neither grouping nor repetition in the stimulation?

There was a time when psychologists were quite ready—too ready—to answer this question by saying "Rhythm is one of the human instincts." As in the case of imitative actions, so in that of rhythmic actions this answer is no longer acceptable. It was excusable only as long as psychologists meant by "instincts" some mysterious property of the soul. It is inexcusable nowadays when the role played by the nervous tissue in conducting excitations from sense organs to muscles is sufficiently understood and when an "inherited action" has come to mean a definite "inherited nervous path" from a definite sensory point to a definite motor point.

The significant fact in rhythm is a tendency for any and all muscular activity to occur in groups made up of several actions and for these groups to be repeated. What, then, is the origin of the general tendency in the individual to perform muscular actions in a group?

What the correlative of the Other-One's grouping is in his nervous functioning, we simply do not know yet. But at least this question should be raised and can be answered with our present knowledge: Is this tendency toward a definite manner of grouping something inherited or something acquired?

In favor of answering "inherited" the fact has often been referred to that only those manners of grouping are likely to be observed in the Other-One which consist of making up the group in question of 2, 3, 4, 6, 8, and possibly 12 and 16, elements. "If the numbers counted are so strangely restricted," it was argued, "the restriction must be caused by heredity, for counting is in no way a restricted habit." The error in this argument is the assumption that "counting" has something essential to do with the rhythm forms. As a matter of fact, when you hear the Other-One count while performing group actions you might as well say that

that is evidence enough for his lack of rhythm. When we say that the Other-One possesses rhythm, we mean exactly the opposite; we mean that we observe him performing a definite group activity without counting, and even while by conversation with him we intentionally make his counting utterly impossible.

Another frequently heard, but inacceptable argument in favor of heredity is the assertion that every child is "rhythmical." But this argument shows only how little time those who advance it have given to the observation of children. It is true that "rhythm" is not the usual result of some years spent in the schoolroom as "knowing the multiplication table" is. Nevertheless, all learning is not confined to the schoolroom, and children obviously do not inherit, but acquire their rhythm, at different ages, a few when they are three, four, or five years old, some more during the years of attending the first years of school, some much later.

The only fact which we have to make clear, then, is the one referred to in the following question: If rhythm is an acquisition, including several acquired habits of action, why do we usually find among these habits only those of 2, 3, 4, 6, and 8-stroke rhythms, and virtually never, excepting a few musical compositions of very few composers, the 5 and 7-stroke rhythm?

We shall, therefore, give in this chapter a plausible answer to this question. And after having reported the facts giving this answer, we shall point out the further, very remarkable, fact that the rhythms when once learned—no matter of which number of strokes and by what muscles they have been learned—can be transferred to any one muscle (or several muscles) which may have been entirely inactive during, and unconcerned with, the acquisition of that rhythm.

Of all the much talked of kinds of "transference of training," (from one sense to another sense, from one muscle to another muscle) this is the only transference of training of which it can be said both that the fact of its existence (as a true transference) is established without doubt and that the way in which it comes about in the nervous system is thus far absolutely unknown and even unguessable. No one has ever yet made the barest suggestion as to the manner of transference of this training within the Other-One's nervous system, tho no one has ever denied the actuality of this particular transference.

First, now, let us report facts which help to give the answer to the former question. One of the most common (all thru life, excepting the first year after birth) activities of the Other-One, the very nature of which implies repetition of grouped actions, is walking. In the exercise of this activity lies probably the chief opportunity and occasion for the acquisition of the plain 2-stroke rhythm.

The Other-One can not walk without repeating the movement. But neither can he walk without composing his activity of two kinds of movements, a heavier and a lighter one. He can not walk hopping along on one leg. But when he alternates the legs, one of the movements is always heavier, or longer, than the preceding and following one. Thus we have a group of two actions. Whether we regard this group as composed of a heavy motion followed by a light one, or as composed of a light motion followed by a heavy one, (accent first or accent last) is quite arbitrary, purely a matter of taste or of the momentary interest in this or that aspect of the entire phenomenon.

Why is the movement of one leg by necessity heavier and more prolonged than that of the other leg? Simply in consequence of the Other-One's right-sidedness. The right leg is, so to speak, the skilful mechanican and the left leg

his unskilled helper. Balancing on one leg is easier on the left, because the skilful part of the process of keeping from tumbling does not consist in supporting the weight of the body (the helper can do that!), but in readjusting the weight distribution quickly from moment to moment by the raised (right) leg, as the tight rope walker balances himself by shifting a heavy pole or loaded parasol held in his hands.

We remember that walking equals balancing plus the functioning of the positive localizing reflex. Balancing is more natural on the left leg than on the right; the localizing action is more readily carried out with the right leg than with the left. In walking as in balancing the heavy part of the work is naturally assumed by the left leg, the skilful part by the right leg. (This is true even when the muscular development of the left leg happens to be weaker than that of the right. You also sometimes see a plumber at work who is a stronger man than his helper, yet the helper has to do the heavy work.) It is no wonder that the officer who wants his soldiers to mark step, orders them to fall heavily on the left leg (not on the right), because that leaves the skillful right leg free to attend to the balancing and falling forward of the body in the proper direction.

When we skate on ice and desire to slide a definite outward leading curve, we discover that we can do that more easily, with less risk of tumbling, on the left foot turning to the left than on the right foot turning to the right. The right leg, swinging in the air in the former case, is a better "balancing pole" than, in the latter case, the left leg. Of chief importance is the choice of the leg which does the balancing; either leg can probably well enough do the merely heavy work of supporting the sliding body.

So, whenever there is any need or occasion for division of labor, the left leg does the heavy and the right leg the light (but skillful) work. And that the work of the less skilled member is likely to be a little more prolonged than that of the skilled member, is also evident enough.

Walking, then, is all thru life a continuous training in performing repeated actions in a group of two, a heavier and prolonged action alternating with a lighter and slightly shortened action. If our anatomy were different, if, for example, we had three legs or four legs instead of two, we should miss this training. The quadrupeds miss it. Four legs, we know from observing dogs, horses, etc., do not co-operate easily in one definite manner; that is, they do not co-operate in the same manner every time. Those animals use now one gait, now another. Therein is found an obvious explanation of the fact that "the animals do not have rhythm." The animals have no chance of acquiring it. The four actions of the four legs do not succeed each other at such regular intervals that they could count as a regular repetition.

Our hands give us no meaner opportunities for such training than do our legs. Especially true is this in manual labor, that is, in the systematized work of civilized man, in domestic work or factory work. The savage, who does not perform much systematic labor, has fewer opportunities of this kind. And the savage has less "rhythm," too, altho some people have the opposite opinion of him. But that savage who often practices dancing must of course be excluded from this statement. Dancing is systematic activity, and, among savages, is regarded as labor rather than recreation.

Having two feet, and having two hands, and being right-sided (or left-sided, that makes no difference)—therein lies the explanation of why the 2-stroke rhythm is common

among human individuals. Why, now, also the 4-stroke rhythm?

There are many systematic occupations in which the Other-One's activity is composed of an effective action followed by a mere "rebound." Take as an instance driving in nails. The hammer is swung down (or forward), but naturally rebounds upwards (or back). But this rebound must not be thought of here as a mere physical matter with which the muscles are unconcerned. The antagonistic muscles, drawing the hammer up, actually begin to contract before the hammer has hit the nail, and are only assisted by the physical rebound. Nevertheless this action of withdrawing the tool is best named simply the rebound, because that name makes always clear what particular action is referred to. Such a double action of effective motion plus rebound is clearly a further example of activities which lead to the acquisition of the 2-stroke rhythm.

But let us recall that, when the Other-One has to drive in a nail, he is often observed to anticipate the strong activity in a weaker one, merely "feeling his way," so to speak, in order to make sure in what curve the hammer must swing to strike the head of the nail. Such a tentative action again consists of a (relatively) effective motion and a mere rebound. The tentative action plus the strong action make up then a total activity consisting of four motions. The four motions succeed each other at fairly equal intervals, so that we can speak of regularity of repetition. The first is the tentative hitting motion; it ranks as the second strongest motion. It is followed by the tentative rebound, which is the weakest of all, ranking as the fourth motion in strength. Next follows the strong hitting motion. And this is followed by the strong rebound, which ranks third in strength among the four. If we mark the four motions, according to their strength, by the letters

A, B, C, D, their succession as above described is B—D—A—C. Here we have in the Other-One's life a common enough activity of the class of habitual activities which lead to the acquisition of the 4-stroke rhythm.

What we said in discussing the 2-stroke rhythm about the location of the accent may be repeated here. It is a matter of taste whether we regard the "group" as beginning with the accent (that is, the strongest motion) or ending with the accent or having the accent somewhere within the group.

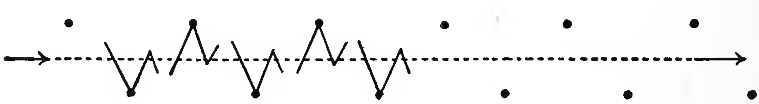
Of some significance, however, and worth mentioning is the fact that we can well speak here of a secondary accent in addition to the main accent. The motion "B," when group follows after group, has before and after itself the motions "C" and "D" which are weaker; it is therefore in a relative sense an accent. The 4-stroke rhythm may be divided into two kinds of 4-stroke rhythms, with and without a secondary accent, for there are also opportunities in life for acquiring a 4-action group habit where the second strongest action is not both preceded and followed by a weaker action, thus giving no rise to a secondary accent.

In this necessarily brief treatment of the whole phenomenon of rhythm, what has been said concerning the probability of the Other-One's acquiring the 2-stroke rhythm and the 4-stroke rhythm must suffice for making it plausible also that there are, altho rarer, opportunities for acquiring the 8-stroke and even the 16-stroke rhythms with or without secondary, tertiary, etc., accents. Our next problem now is that of showing by examples what opportunities the Other-One has for acquiring the 3-stroke rhythm, the 6-stroke rhythm, and maybe the 12-stroke rhythm.

One very obvious chance for changing a group of two actions into a group of three is offered by the necessity arising of performing such an action as that of nail driving

alternately toward the left and the right, or alternately up and down. The Other-One hits, let us say, a nail on a board before him below the level of his chest and carries out the rebound as previously discussed. But now, suppose, he has to hit a nail on the lower surface of a board before him above the level of his chest. A third movement, in the downward direction, has to be added to the other two merely in order to get ready for the work on the upper board. Let us call this added movement the "preparatory" movement. It is probably the weakest of the three. The hitting, the rebound and the preparatory movement then constitute the group of three. There certainly are in the Other-One's life, especially in industrial life, opportunities for having to change the direction of work alternately into the opposite direction.

Here is another concrete example. Imagine a gardener having planted a double row of plants like the dots of our figure "Steps creating a 3-stroke or 6-stroke rhythm." In order to keep the loose earth, just thrown around the roots of each plant, from drying, it is necessary to compress it and thus render effective the capillary attraction which draws the moisture from the lower soil. The quickest way



STEPS CREATING A 3 OR 6-STROKE RHYTHM.

of doing the work is to walk along the center line of the double row and to step, with the full weight of the body, on each of the places which need compression, using, of course, alternately the right and the left foot. Now, try to walk ahead, doing this, and observe how your legs most naturally act during this procedure. While you are standing on your right foot, the muscles of your right leg are

strained in such a way as to keep the leg straight and able to support the weight of the body, but not in such a way as to throw readily the weight of the body upon the other foot. For this a complete readjustment of the muscles of the right leg is requisite. To bring about the muscular readjustment, you most naturally let the body fall lightly upon the left foot and let it swing back to the right. Thus you assume that new position on the right foot in which the tension of the various muscles is adjusted so that the full weight of the body can be thrown on the left foot forcefully and skillfully. The left foot now hits exactly the spot in the left row on the ground where the compression of the soil is needed.

What, then, have you really done instead of stepping simply from the right foot upon the left? You have made two intermediate steps of a much less forceful kind, merely preparatory to the proper stepping on the loose soil. Before you now step on the next spot in the right row, you make again two preparatory steps, and so you continue your agricultural work most easily (that is, most naturally) and most effectively. Between each two compressing movements there are always two different preparatory movements, both of an easy character.

The 6-stroke rhythm can be understood most easily as the total activity including both the activities on the alternating sides. If, for instance, we consider the Other-One's hammer movement toward the left as being under special circumstances accidentally of more consequence than the hammer movement to the right, and therefore as being stronger, we at once have a group of six motions among which the first has the main accent and the fourth a secondary accent. But undoubtedly there are also opportunities in the Other-One's life for acquiring the habit of a group of six actions among which the first has the main accent and the

third and the fifth both have secondary accents; or of six actions among which one has "the" accent, there being no secondary accents whatsoever.

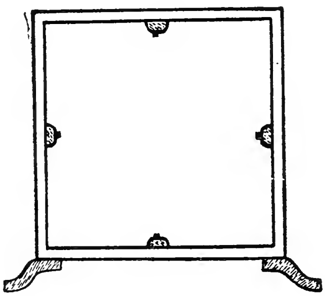
Thus far we have convinced ourselves that opportunities are not infrequent in the Other-One's life for acquiring the 2-stroke, 3-stroke, 4-stroke, 6-stroke, 8-stroke rhythms. We use the plural form "rhythms" advisedly, for it has already become clear to us that the Other-One does not acquire "rhythm" in the abstract, but particular rhythms of so many actions per group. Who, now, will suggest to us probable life activities of the Other-One in which five or seven regularly repeated actions are unified into groups having each an accent?

The fact that such activities are extremely rare explains to us at once why 5-stroke and 7-stroke rhythms are so rarely observed in playful activity, in music, in poetry and elsewhere in the Other-One's life. There is no need of the almost ridiculous assumption that creative Nature possesses such a dislike (reminding one of the "horror vacui" in medieval physics) for the numbers "5" and "7" that she left these out in making us a gift of "rhythm."

However, while opportunities for acquiring the 5-stroke rhythm are actually rare in the Other-One's life, we should be able to create such opportunities artificially and intentionally if we are interested in the matter. What, for instance, would make up an activity of this kind? If any one suggests counting "1—2—3—4—5" and putting an artificial accent every time, say, on "1," we may accept this as a possible method of acquiring this rhythm, for there would be regularly repeated (speech) actions of which every fifth would be the strongest. But this method of using a counting exercise in order to acquire the rhythm would turn out to be an exceedingly poor method.

A good method has been found to be the following one, which employs a wooden frame, a square about two feet high, placed upon the table before the Other-One whom we desire to train. The frame has four buttons on the inside, as shown in the figure, which may be furnished for experimental purposes with bells or recording devices of any desired kind. The Other-One is given a heavy spherical rubber mallet and asked to do a particular kind of work on the buttons of the frame. He is never told to count anything. Counting is never mentioned to him. All possible varieties of rhythm can be acquired by properly chosen forms of exercise on this frame (even the 11-stroke and the 13-stroke rhythms),—without any counting whatsoever.

We tell the Other-One to hit the left button "tentatively," carry out the "rebound," hit the same button "strongly," carry out the "rebound," and then add a "pre-



FRAME FOR LEARNING UNUSUAL RHYTHMS.

paratory" motion in order to get ready to do exactly the same with only sides exchanged to the button on the right of the frame. Immediately after that it is done again on the left, and so forth alternately. The activity consists of five regularly repeated actions grouped, so that every fifth action in the repeated groups has an accent. When the Other-One has taken this exercise five minutes a day for four weeks, he tells us he now has "the 5-stroke rhythm"

comparable in every way to the 2-stroke and 3-stroke rhythms which he previously possessed. There is then no reason left for believing that those other rhythms were not also acquired. Merely occasions for acquiring them occurred at an earlier time in his life,—and occur with some probability some time in everybody's life.

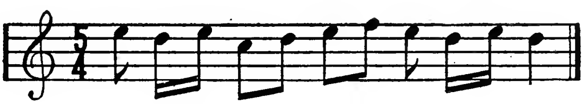
Or, we tell the Other-One to hit the left button, then carry out the rebound, then make a preparatory movement for doing the same thing toward the right button; but, after having done it on the right and having made the second preparatory movement, not to continue on the left but to make an additional preparatory movement thru a quarter circle in order to get ready to perform the whole group of the six motions now up and down, as he made them before right and left. The exercise leads here after a few weeks to the acquisition of a 7-stroke rhythm which appears perfectly like any ordinary rhythm.

The 5-stroke and 7-stroke rhythms can not, therefore, be said to be essentially different in origin and quality from the usual rhythms. The only thing that can be said of them is the fact that occasions for accidentally and incidentally acquiring them are very rare.

Musicians have begun to use the 5-stroke and the 7-stroke rhythms, in compositions of the highest quality. Maybe some poet will have the courage to follow in their footsteps. The fact, however, that musicians and poets have virtually abstained from using these rhythms, has nothing astonishing for us. Few are the musicians (for example, Tshaikovsky) who have these rhythms, and few are the lovers of music who have them. There is little inducement, then, for any musician to employ these rhythm forms in his compositions.

But we hear them once in a while, and not only in music of the European variety. The writer has seen Arabs in a

religious street procession, with flags and brasiers in their hands, walking along in dancing steps, five steps in a group. And he found there the confirmation of his previously established conviction that the alternate change of a lateral or vertical activity into a similar one in the opposite direction (as above described) is probably the most influential factor in establishing rhythms of the odd number kinds. These Arabs in the procession face at every fifth step alternately the spectators on the right side and on the left side of the street, saluting now the one side, now the other. And the Arabic music band plays a "march" which, very fittingly, with perfect distinctness consists of five equally long tonal phrase elements to the measure. The musicians them-



ARABIC MARCHING DANCE.

selves dance while playing. The music is here reproduced. It is endlessly repeated. (There are no harmonies.) The old assertion that all "true" rhythms contain only numbers made up of the prime numbers 2 and 3 as factors is clearly a myth. The word "true" in this sense is meaningless.

The fact has already been stated that any particular rhythm, after having been acquired by the Other-One thru the acquisition of a particular habit of concerted (serial, or group) action,—amazing as this may seem—transfers itself with ease to virtually any arbitrarily chosen motor point, or motor points, of the body. The nervous system as a whole, that is, is after that habit acquisition capable of conducting, anywhere and anywhence within it, a particular succession of stronger and weaker stream waves with special ease. How that comes about is unknown. But the fact of this transference is only the more remarkable.

When the nervous system is once in possession of this peculiar capacity and tendency, we say that the Other-One has "rhythm," or, more correctly, that he has a particular rhythm, which may "crop out" at any time in any muscles of his body. Whenever he happens to execute this rhythm in response to a perfectly regular (that is, known by us to be perfectly regular) succession of stimuli, tones, drum beats, ticking noises, or what not, he is likely to answer a question in this respect by telling us that these sounds are not all alike, that they themselves "have rhythm." Since we know better, and since he will probably contradict himself after a while, we have here a new example of those reactions which are "wasted" and which, therefore, are called "illusions." Rhythm experiences are often, and quite rightly, mentioned in the text-books as samples of illusions. We all probably have had such illusions of rhythm while riding at leisure on a steamboat or in a train. We find ourselves able to change the rhythm of the train at our own sweet will. The stronger our own habits of group activity are (for instance, if we are passionate dancers), the more readily come these wasted reactions, these illusions.

An especially interesting transference of rhythm is the transference to the function of the speech organs. We call the result poetry, without, however, wishing to convey the idea that this is the only characteristic or even one absolutely indispensable property of everything which goes properly under the name of poetry.

In all his games and recreations the Other-One enjoys the ability to perform easily an apparently difficult feat, or, as in the circus, to see other persons or animals perform easily apparently difficult feats. So he enjoys poetry. Merely to speak in prose correctly and logically does not appear very difficult to the Other-One. To act rhythmically does

not either appear very difficult in producing meaningless sounds. But a combination of rhythm in speech with good grammar, syntax, and logical sense seems so impossible that when it is successfully accomplished, it is very enjoyable.

Of course, there is rhythm also in prose. But it is not applied with such long continued regularity as in poetry, where the regularity is called the "meter."

Wrong ideas are often entertained with respect to the rhythm of music. Only in dance and march music is the rhythm of music comparable in regularity to that of poetry with a definite meter. In all other artistically performed music the rhythm is much more comparable to the rhythm of prose than to that of poetry. That all music is written in measures has a purpose other than that of securing a "meter." The written musical measure is a pseudo-rhythmical group, introduced merely for the practical purpose of adjusting the time relations of the tones to some standard and aiding several performers in finding out how to play together.

Quite erroneous would be the idea that the fact that people dance is one of the results of a transference to the feet of any particular rhythms previously acquired. Such a transference is, of course, not impossible; but it would be much truer to say that the Other-One has rhythm because he often dances than to say that he dances because he has rhythm. The main origins of the dance can be found in special (real or imaginary) human needs, as a study of anthropology reveals, not in an irresistable impulse to apply rhythm to otherwise unrhythmical locomotion. On the other hand, dancing, having once established itself as a habit in the Other-One, becomes one factor of great importance for developing in him particular rhythms.

The value of rhythm for increasing the efficiency of labor has often been spoken of in books. But while rhythm has

such a value, this value is usually overestimated by the authors. As with respect to the dance, so it may be said with respect to the performance of systematic labor that more frequently the Other-One can be said to have rhythm because he often labors than that he labors efficiently because he has rhythm.

The workmen of countries with a somewhat retarded civilization (the Orient) are often quoted as making their simple labor performances more efficient by forcing it, thru the medium of song, to be rhythmical. The writer, in making observations relative to this question, reached the conclusion that the song usually serves, mainly or even exclusively, an entirely different purpose. For instance, when three laborers tamp the clay into a form in order to construct the wall of a building, they sing. But they sing quite obviously not in order to make their work rhythmic. Their work is not rhythmic. The raising of the heavy tamp is so slow, and its downward motion so quick, that there is nothing rhythmic in the individual laborer's work. And they succeed each other in tamping—so much is true—, but the succession is so irregular that one can not speak of anything rhythmical there either.

Nevertheless they sing. But each one sings while he is doing his share of the work. And the other two laborers, during their brief pause in their work, pause generally in their singing too. The song, then, is a signal meaning (altho the words sung literally do not have to mean this): "I have done my share of the work; now do you yours." And the second laborer raises his tamp in response to the signal, in turn also takes up the song and thus gives the signal to the third laborer that his time has come to do his share. It may happen that the third then raises his tamp, but makes three or four quick and weak impressions on the clay, here and there, rather than one heavy blow if the latter is less

needed at the moment. He lengthens the singing a little. Signaling to each other and thereby encouraging each other to continue their heavy task,— that is the purpose of the song rather than to increase the efficiency of their labor by forcing it into a (here virtually impossible) rhythm.

CHAPTER XVI

HOW THE OTHER-ONE TALKS AND WRITES TO HIMSELF.

There is no need of describing in detail, in a psychology text-book, the invention of script. Only this let us recall that signaling by drawing a design of an object is a very natural invention. If the traveler in the wilderness, for example, hides provisions and wants his friends, who will come later, to find the hiding place, he carves or paints the outline of an animal used for alimentation on the tree or rock beneath which the provisions are hidden. Of this nature are also the famous Egyptian hieroglyphics.

These visual signals, once invented, quite naturally become substitutes, as occasion arises, for auditory signals. That is, they become phonetic characters in which the abbreviated picture represents the sound of the whole word that is the name of the object. If your voice does not carry the word "meat" across the valley to your friends on the other ridge, you send a written message, the phonetic symbol which represents that word, across to your friends.

Soon the phonetic symbol comes to represent, no longer that whole word, but only the chief sound, usually the initial sound, of the word. Phonetic script is then invented. Phonetic script is a kind of frozen speech, just as in a later (but actually much simpler) invention the disk of a talking machine is a kind of frozen speech.

Altho speech is nothing but a development into complicated habits of the original signaling reflex acting on the other animal's auditory organ, it assumes a new role in the Other-One's life thru being used by him in order to signal to himself. It is not necessary for us to support by far

fetched evidence the assertion that the Other-One often signals to himself, often speaks to himself. Everybody knows that. But what is the use of doing that? Its use is, in philosophical terminology, generalization and abstraction. It is our business here to understand it as a nervous function.

1. A child, in the presence of such things as bread, fruit, edible roots, meat, impressing his eye, learns to pronounce the word "food." Instead of handling these things in accordance with his reflexes and already acquired habits, he speaks the word which his parents and other people of his environment use as the common name of these things.

2. On the other hand, when the child's ear is struck by the sound "food," he learns to respond (if otherwise than by repeating "food") by such particular muscular activities as are adapted either to the preparation and cooking or the consumption by the mouth of bread, fruit, edible roots, and similar articles. The word heard takes the place of the things seen in the nervous functions which result in handling. From now on, whenever the word has struck the ear, the muscles which co-operate in properly handling these things get ready to work rather than other muscles get ready to handle other things which also impress the eye at the time. The nervous paths serving the latter impressions are at a disadvantage in not being "cleared for action" (by deflection or by preoccupation) thru the word signal commanding them.

Under (1) we mentioned the speech action "food," under (2) the speech sound "food." We know, however, that the sound resulting from the speech action stimulates the ear of the very person who speaks. Thus the motor action of speaking and the resulting excitation of the ear become a double link inserted between the mere sight of the article of food (among other things) and its proper handling

(among other ways of handling). This insertion of a new link into the chain of functions is not an unnecessary, uneconomical complication. It is a helpful link because it is "the same link" however different the visual appearances of the articles of food (they are all called by this particular name "food") and however different the ways of handling and preparing them before swallowing (they are all called "feeding"). Thus stimuli most different and reactions most different are all brought together into one sensory-motor class.

This classing together, in the terminology of logic, is "generalization." In the life of animals generalization is virtually absent because, without speech, such classing together of functions is very unlikely to occur. But let us not think that it is absolutely lacking in animals. A dog, for example, classes together certain sights ("outdoors," in contrast with "indoors") and certain actions, and performs the latter only outdoors. Nevertheless, the difference between human beings and animals may well be described by saying that the latter do not generalize, or by saying, as we did in the first chapter of this book, that the former are thoughtful and the latter are thoughtless, which refers to exactly the same observable facts.

Let us imagine another instance. A child has a solid article in his hand, or between his teeth, or in a pocket, or beneath his feet. An adequate stimulus causes him to transfer it from his place to a place farther away occupied by another person. The child, transferring the thing, is stimulated by the sound "give" and pronounces himself, imitatingly, this word "give."

But the child also learns to respond to the auditory stimulation "give" by a motion transferring whatever is transferable.

Later he is busy transferring, hears the word "give," repeats it by pronouncing it himself, responds to his own voice by transferring, and thus has within his action of transferring a speech function which seems to be a perfectly superfluous accompaniment and superfluous representative of the action of transferring.

Transferring. . . . . transferring continued
Transferring——saying "give"——sound of "give"——transferring continued

This representative, accompanying its constituent, would indeed be an unnecessary complication of nervous activity, were it not for the fact that the additional function is practically the same however different the manner of motion transferring the article in question: by stretching out the hand, throwing, kicking, dropping from an elevated place, rolling down a hill side, not to mention sending it by a messenger, by mail, or by any other device of modern transportation. This establishment of a definite function identical in spite of untold variations of the motor activities which it represents—they are all called giving—is obviously also a generalization. Or, in the terminology of logic, it is an abstraction. Abstraction, then, is a special case of generalization—generalization, not with reference to objects, but with reference to relations (spatial transference, in the instance discussed).

The difference between the biological functions in ordinary generalization and in this special kind of generalization, abstraction, might be described thus. In ordinary generalization the object handled is of main significance. The manner of handling it is of importance only in so far as the object is distinguished from objects of a different class by the proper mode of handling it,—for example, "food" is an object to be eaten by the responsive animal. In abstraction the mode of handling is of main significance. The object itself is important exclusively in so far as, if there

were no object whatsoever, no handling of it could have occurred.

The purpose of our present discussion is not to give a lesson in logic. Our intention is to show briefly, but conclusively, that practically no generalization or abstraction is possible without speech, and to make clear by concrete examples what is meant biologically by such terms as generalization and abstraction. In order to make the significance of speech in the Other-One's individual life—over and above its social significance in signaling for co-operation in actual labor—still clearer, let us discuss a third concrete sample case taken from life.

The Other-One, after having had both the speech experiences above described of "food" and of "give," happens to meet a beggar who "signals" to him with the words "food, give." The Other-One then looks about until his eyes are arrested by an article belonging to the class "food." A piece of bread may serve to bring this about. He then approaches the bread and would now respond to its sight simply by the most firmly established habit, by taking it and eating it, had his ears not been stimulated by the sound of the word "give" too. So he responds by giving the piece of bread to the beggar.

Similar experiences take place quite frequently in every child's as in every grown person's life. Suppose the address has been "food, give, hungry." The child thus learns to react to the signal "hungry" in the same way as to the sentence (if these two words may be called a sentence) "food, give." He learns to react to the word "hungry" by looking about for edible things, taking hold of them, and transferring them to the other being. There is new economy by means of a new "abstraction," one word taking the functional place of several.

What a wealth of possible actions is thus placed under the control of the single speech function "hungry!" The Other-One, when fully experienced, hearing this word, looks about until an edible thing strikes his eyes. But if this does not happen to his eyes, other reactions follow in a more or less definite series. He may put his hands into his pockets to search for food. He may walk home in order to find food there. He may open his chest or cabinet, take money from it, and go to the store where food is for sale. Or he may go out to his fields, cut his wheat, and store it away under the roof of a barn in order to be able to give food at a later time when the sound hungry may strike his ear again. Not having any wheat mature on his fields, he may take out his horses and implements and plow the ground on which wheat is only to be sown. He may attend, as a student, an agricultural college where he learns how to grow wheat most successfully on his farm. He may vote in favor of his government spending money for the support of such a college. Further think of the innumerable possible activities which make provision for the transportation of the food from place to place, from the producer to the consumer! To enumerate even those activities which are more directly controlled by the word hungry, would require a volume. Of the activities which we have mentioned, some are rather remotely dependent on the abstraction "hungry." The more remotely they are dependent on it, the more numerous, of course, are the other abstractions on which they are also—more or less directly—dependent, so that, then, the actual motor response becomes more and more the resultant of many components, of all the activities controlled by all the abstractions.

We have thus far spoken of the word "hungry" only as denoting a sound, stimulating the ear and controlling by means of the nervous paths diverging from the ear a vast

number of highly complicated motor responses. We said above, that the word hungry was often heard together with the words food and give. At such a time it must have been imitated by the child in question. It is plain, however, that the same word, hungry, is also heard in other situations, especially at the time when the members of the family assemble to take their meals together. At that time the child's sensory points of the stomach are likely to be excited by the physiological condition called hunger technically by the physiologists. Accordingly, the child learns to say "hungry" in response to that sensory excitation.

Whenever he responds thus, he produces the sound of the word, and the sound acts on his own ear. Quite naturally, then, the speech function "hungry" becomes an intermediate link between the sensory excitation of physiological hunger and that vast number of responses above mentioned, including such things as the deposit of a ballot in a box, all serving, with greater or less directness, to dispel hunger not only in others but in himself.

It is not difficult, then, to understand the value of abstractions to the Other-One. They serve to make ready, instead of the simple reflex corresponding to the stimulation or a simple habit having taken that reflex's place, an enormous number of complex motor responses among which for actual execution a selection is made, that is, is conditioned, by the other sensory factors of the situation and by the motor tendencies of the abstractions belonging to them. The functioning of abstractions (his "thoughtfulness" in popular terminology), which is the distinguishing feature of man's life as compared with that of animals, is made possible by the acquisition of speech.

The speech functions here described are habits in no essential manner different from other habits. The mere fact that the muscles in question are the muscles of our speech

organs and not those of our hands and feet, does not establish an essential distinction between these and other habits. The laws of nervous function governing the formation of habits are the same for the "generalization and abstraction" habits and for other habits. In ordinary life we distinguish them often by calling the other habits simply "habits," or motor habits, or manual habits, or postural habits, and denying the name "habits" altogether to the habits of generalization and abstraction, giving them instead such names as memory, or reasoning power, or thought. This division into two classes has its advantages from the sociological point of view; but it has little to commend it from the psychologist's point of view.

It would be a complete misunderstanding of the functioning of speech in the generalizations and abstractions of an adult, if we should think that in every such case he must be heard to speak or mutter to himself in a manner audible to others. We know that sometimes he can be heard to speak to himself. But the muscular contractions may be far too weak to result in actual sound production. And yet their action as kinesthetic stimuli may be strong enough to bring about the effects which their action as sound stimuli would have brought about. It goes without saying that the kinesthetic and sound stimulations which are always (normally) the simultaneous results of speaking, come to take each other's place with absolute definiteness on the sensory side of all habit functions in which either the one or the other plays a role.

Moreover, it is not even necessary, in order that the speech organs may play their parts in generalizations and abstractions, for their muscles to contract at all. It is quite possible, tho not as yet a proved fact, that nervous currents, after having passed into muscles (motor points) may directly under certain favorable conditions pass over into

the sensory points of the same muscle fibers without causing them to contract at all,—and then pass on from these sensory points in the usual manner. If that is true in certain cases, these muscle fibers would act simply as if they were higher centers within the nervous system. Nothing is thus far definitely known about this question.

In the development of generalized (abstract) nervous functions an enormous step in advance is made when mankind invents script. The written language can accomplish much that is denied the spoken language. First, it enhances the preservation of the Other-One's generalizations for his own later use. Secondly, it removes practically all the limits of space and time from mutual signaling among several individuals, and thereby also removes all limits from placing one individual's generalizations at the disposal of other individuals, thus saving them in the case of innumerable generalizations the time necessary for their invention.

As to the preservation of any generalization for the individual's own use, it is plain that, as long as generalization is mediated only by the spoken language, it depends exclusively on the properties of his own nervous system. Just so long will the generalization persist, as a path of low resistance, established by the speech function, leads from the sensory points of, say, hunger to a common central point, and another one from a common central point to that vast number of responses previously indicated. But such a path of low resistance can continue to exist only if it is constantly re-established, so to speak; for we know that a path whose resistance has been lowered by individual experience tends to resume gradually its original high resistance. "The experience is forgotten."

After the individual has acquired—by a simple replacement of response—to the sight of the written word the same manifold possibility of responding as to the sound of the

same word, the time limit of preserving the generalization depends no longer on the delicate properties of his nervous system, which is so easily influenced by new experiences as well as by normal and abnormal physical processes like fatigue and disease, but on the physical properties of the material on which he has written the word. It is true that, quite recently, one has learned by phonographic records to preserve the spoken word. But the limitations of this method are obvious, and, whatever may be its significance for the future, in the past at least the individual has had to depend for the preservation of his generalizations on the written word, the memorandum-book.

Of course, we use here and in the following the term "word" in a very wide sense, including therein all written symbols of any kind, especially those of mathematics, even all kinds of geometrical drawings, and the diagrams and symbolic letters of physics, chemistry, and all other sciences.

Secondly, we stated that by the substitution of the written for the spoken word communication of the individual's generalizations to other individuals has transgressed almost all limits of space and time. As we read a letter despatched from the opposite side of the globe, we learn what generalizations were most powerful in the nervous system of the individual who signed the letter, at the time—weeks ago—when it was written. As we peruse the book of an author long since deceased, we learn what generalizations of his own he thought desirable to communicate to his contemporaries and those who were to live after him. As we uncover the tombs of the Egyptian kings, we learn what generalizations chiefly determined their actions thousands of years ago, while they were preparing for the common destiny of all individual life, for death.

Posterity, opening our books, may learn what generalizations affected our nervous system so strongly that, in addi-

tion to using them in our individual life, we had them reproduced in the printer's office. Thus all mankind becomes a unit, spatially and temporally. The individual's experiences are no longer useful to him and to the few people of his direct environment alone. All other individuals of the present and future may profit by them. Science is the sum total of all those generalizations which the experience of mankind has invented, selected, and collected as the most useful for the control of the muscular response called forth by sensory excitation.

The statement of the last sentence calls for further elaboration since the work of a scientist, especially to those not very familiar with it, seems to be altogether different from that of the ordinary man, say, the farmer plowing his field,—seems to belong to a category of activity other than that of motor (muscular) response to sensory excitation.

When, in the evolution of civilization, the writing of words and other symbols of generalization has firmly established itself in a sufficiently large group of men, in a tribe or a nation, the written symbols become a special class of important objects to which, however artificial their origin, man has to learn to respond in order to be successful in the struggle for life, as formerly he had to learn to respond to those objects alone which have their origin in nature.

Moreover, young people selecting a class of objects to which to devote their lives as specialists may now not only select from the natural objects, but may choose even this class. Their life work, then, consists in responding to written symbols by writing symbols and, of course, also by pronouncing them, as in oral teaching. The scientist's work, aside from experimenting, that is, testing the value of his generalizations by skillful appeals for an answer to nature, consists in combining, on writing paper, symbols al-

ready existing into new groups and inventing for each group of generalizations which has been demonstrated by experiment to be a useful combination of symbols, a new name, that is, a new symbol of generalization.

All this is, clearly, motor activity in response to sensory excitation. The only distinguishing features are these, that the scientist's motor activity does not require muscles of any great strength, and that it does require an enormous amount of learning, of variations of response, before it can begin to be of any value to humanity.

Let us take an example from the most ancient of all the sciences, which, notwithstanding its age, is still and will always be the foundation of all others,—from arithmetic. No one doubts that the most ancient symbols for larger and smaller groups of things were diagrams of familiar objects. The Roman numerals V and X, for example, are diagrams of one hand with fingers spread out and of two hands united in opposite positions at their wrists. Even if these diagrams, originally, signified only a quantity portable in one hand and a quantity portable in both, they would already be generalizations, for many are the things or substances which can be carried by hand.

If not at once, at a later period, these diagrams came to signify five and ten. They are then a step further removed from natural experience; they have assumed to a further degree the meaning of a generalization (or, if you prefer, of an abstraction). When a person counts, up to five or any other number, he enounces in regular order one of the words of a series which he must previously have learned, while he removes to a position of repose, say, with his finger on the table, or with his turning eye in the subjective field of vision, just one more each time of the objects counted. When written symbols like our Arabic figures are substituted for the spoken words, new generalizations are made possible.

What is the significance of the plus sign? If we write it in $7+8$, we invite the reader to count a group of seven things of his own choice and another group of eight as if they were only a single group of countable things. The plus sign, then, is a generalization for any kind of sensory-motor activity arranging the things as if they were a single series and counting them thus. The minus sign is a generalization of a similar kind. In $7-4$, for example, we express the question: How many times more do you count after 4, till you enounce 7? The minus sign, then, is a generalization for any kind of sensory-motor activity arranging the things of one series as if they were two series.

The multiplication sign presupposes the experience of the plus sign. By writing 3×7 we invite the reader to perform the work of adding 7 plus 7 plus 7. Modern mathematics has greatly increased the number of such generalizations,—think only of logarithms, not to mention higher mathematics. Yet by degrees they can all be reduced to the relatively simple activity of counting a series of things.

Another example of a scientific generalization might be taken from mechanics. Remember the formula $\frac{1}{2}mv^2$, generally used in measuring our experience of "force."

Man, in his intercourse with nature, learns how to resist moving objects and also how to utilize the motion of objects (a hammer, for example) for his own purposes. He learns that he has to exert more muscular energy if the object resisted is heavier, and also that his work is more effective if he uses a heavier tool. He generalizes his experiences of resistance to objects and of work by the aid of objects—experiences to which he has already given the general name of "force"—by pronouncing the word "mass" in order to express their quantitative aspect. In writing this word he abbreviates it by writing simply *m*.

By further experience man learns that he has to exert more muscular energy and also that his work is more effective, if the object in question moves more quickly. These experiences, in addition, he generalizes in writing by uniting the symbols "mass" and "velocity" in a single formula, conecting them by a sign of multiplication.

At our present time, however, one does not write simply $m \times v$, but $m \times v^2$, multiplying v with itself. This is done because the formula $m \times v^2$, in algebraic relations with other formulas expressing other important experiences with heavy bodies, is in general more convenient. Still, this greater convenience was only gradually recognized by scientists. Two hundred years ago the question was debated in heated controversies between the most distinguished scientists whether the symbol mv or the symbol mv^2 was a more useful tool of generalizing human experience, or, as they expressed it,—talking as if force were a measurable thing among the other objects in nature, instead of a mere generalization invented by man—"whether force was proportional to velocity or to the square of velocity."

At present the latter formula is generally preferred, but slightly modified by the addition of the factor $\frac{1}{2}$. This simplifies again the algebraic operations, for the formula $\frac{1}{2}mv^2$ can be put down directly as equal to a certain other very important formula of mechanics. The usefulness of the equation thus formulated is the only reason why our scientists have become accustomed to using exclusively the formula $\frac{1}{2}mv^2$ in their generalizations of the quantitative aspect of the qualitative generalization of "force." (We may mention, by the way, that the use of the equation in question gradually brought about a change of name of the generalization $\frac{1}{2}mv^2$, so that it is nowadays called "work" in the text-books of physics.)

Force, therefore, is by no means, as some speculative philosophers would make us believe, a reality given by nature, and truly measurable only by a single formula, but a mere abstraction created by man to suit his needs, and expressed by that combination of algebraic symbols which best suits his needs, practical and theoretical,—an abstraction from experiences so varied and complex that without this generalization we could not respond to the quantitative aspect of any one of them with any definiteness, we could not measure them.

In school and all through life we find ourselves compelled to respond to traditional audible and visible symbols of generalization as well as to the situations presented by nature. We gradually learn to respond to these kinds of stimulations most successfully: we acquire scientific habits. An example of a habit of responding to symbols of generalization—or rather an example of a large group of such habits—is the multiplication table. To the phrase "seven times nine" we at once add, by habit acquired, the word "sixty-three," without having first to do any counting, thus saving a large amount of time.

In a similar way one learns, long before he acquires the multiplication table, to combine words into sentences and sentences into periods, and to draw conclusions expressed in further sentences, without first having to devote time and energy to perceiving the things which are meant by those generalizing words and sentences.

The enormous advantage of substituting this handling of words for the cumbrous handling of things is clear enough, but the danger of speculation is clear too,—the danger of combining words and of thus drawing conclusions, that is, of expecting the things to agree with the last group of words manufactured by us, for no better reason than this, that we know our succession of sentences to have been con-

structed according to the rules of grammar, syntax, and logic.

This danger does not exist in the case of the multiplication table. Here, in our most elementary quantitative generalizations, things always agree indeed with our conclusions. But our purely qualitative generalizations are so inexact that the things, when we perceive them, often turn out to be quite different from what we, guided only by our habits of handling words, expected to find them.

CHAPTER XVII

IF THE OTHER-ONE IS BORN BLIND, OR DEAF,—WHAT THEN?

That the loss of any sense organ involves many difficulties in the Other-One's life we know from experience. And that is also to be expected as soon as we understand that his life is a continuous reaction to excitations occurring in his sense organs. But a detailed discussion of these general difficulties would be out of place in an introductory text-book like this. It would lead us into the medical and other sciences.

A reason, however, for discussing here certain consequences of a loss of certain sense organs is the fact that this loss may seriously interfere with the Other-One's living as a member of human society. The signaling reflexes, we have seen, are of particularly great interest to the psychologist because of the role they play in establishing social relations among the individuals. While discussing the relative value of the visual and auditory signaling reflexes, we had to point out that, contrary to our first expectation, the auditory signaling reflexes seem to be more significant than the visual signaling reflexes. Keeping this in mind, we no longer wonder at the fact—not statistically proved or provable, but generally acknowledged—that deaf people are more likely to be unsocial, morose, suspicious of their fellow men, than blind people. Of course, if people in adult life lose one of these two senses, they are during the period directly following the loss more conspicuously

affected by the loss of sight than by the loss of hearing. This is natural, for the former loss requires in general a much more profound change in the manner of performing one's daily routine work. But after this adaptation has occurred, and the individual has become to some extent reconciled to his loss, the change in personal character above referred to as distinguishing the deaf from the blind is obvious enough and is clearly the result of the great significance of auditory signaling for social life.

But in this book our chief interest in the loss of various sense organs has its basis in the fact, discussed in the last chapter, that the Other-One's supremacy on earth among all the species of animals depends on his acquisition of language. Without his language that feature distinguishing man from the animals, that is, the use of generalization and abstraction, his "thoughtfulness," would not exist. And in order to acquire language, all sense organs are not of equal importance.

Having once acquired a spoken or written language and having learned to use it for generalization and abstraction, the Other-One may then lose his sense organs needed for the acquisition of speech, or of its equivalent, script. And still he would continue to use generalization. It is not the adult, therefore, who concerns us here in this discussion of the effect of the loss of sight or hearing. It is the child who becomes blind before learning to read and write and the infant who becomes deaf before learning to speak the language of his family, who interest us here. Briefly speaking (but allowing for a certain extension of the time of loss beyond the time of birth, as hinted at in the last sentence), we may ask: How different will the Other-One be if he is born blind, or born deaf, or born both blind and deaf?

The signaling *reflexes* which the Other-One possesses are far too few and too simple to serve as the mediating link, studied in the preceding chapter, which establishes that nervous function deserving a special name and given the name of "generalization." The Other-One must *learn to speak,* he must acquire a relatively extensive complex of habits, "language," in order to generalize. For acquiring language habits he depends largely on "imitative reflexes," since schools, in which language is, or languages are, artificially taught, are a very recent invention of mankind. In spite of all the vague glorifications of the "instinct of imitation," man, as we have convinced ourselves, virtually has no other imitative reflexes than the auditory ones. Without having the sense of hearing, therefore, man can not by reflexes imitatingly acquire a language.

If the Other-One is born deaf, he never acquires a language unless he is sent to school. Being born blind, on the other hand, does not interfere with his learning to speak the language of his people. The lack of schooling, therefore, has a much more profound effect on the deaf-born than on the blind-born. The lack of schooling condemns the deaf-born child to remain intellectually on the level of animals. When we use here the term "intellectual" or "intellect," we use it as an abstraction referring to the concrete fact that a being uses in his life, to a larger or lesser extent, generalizations and abstractions. He who deprives a deaf-born child of schooling, deprives him of what makes him a human being, of his "intellect." He degrades him to the level of animals. If in a modern civilized state the question could be raised at all, whether it is more indispensable to have schools for the deaf or schools for the blind, the answer is easy to give. The school for the blind raises an intellectual, "thoughtful," human being to a mere-

ly higher level of intelligence. The school for the deaf raises to a human level a being who would, without it, remain on the level of the animals.

The fact just stated has always been recognized in human tradition. In former centuries, it was customary to say, on hearing of the birth of a deaf child, that the parents were the unfortunate possessors of a being which had inherited their material form, but to which the Creator had refused a "soul." In other words, they had an animal looking like a man.

That people should have expressed the expectation that a being would never in his life use generalization and abstraction, by saying that he had been given no "soul," would strike us merely as a rather ridiculous kind of superstition, if that manner of referring to these unfortunates had not had its serious practical consequences. When a being is so unsocial as a deaf being generally is, so unresponsive, so unteachable, there is no great inducement for his people to make the sacrifices involved and give him a schooling. But since this disinclination of the parents to the establishment of a school for their deaf children, or to the appointment of a tutor for a deaf child, was still fortified by the use of the abstraction "lack of a soul," it is no wonder that the education of the deaf-born child was something unheard of in ancient and medieval education and is not an outstanding feature in the history even of modern education. Who but a fool, it seems, would think of appointing a tutor for animals,—and deaf-born children used to be regarded as animals.

The men who could free themselves from tradition, look the facts in the face, and recognize that deaf-born children were as teachable as others, that they merely had to be taught by different methods, may well be counted among the geniuses of mankind. That alone, however, is not the rea-

son why we mention the names of some of these men below. We mention them also because in the history of the education of the deaf we have a beautiful illustration of the fact, innumerable times repeated in human history and psychologically interesting, that a vague rumor that something apparently impossible has been done somewhere somehow, and that therefore it can be done, has often encouraged a man to rediscover something independently and to claim the priority of the discovery quite honestly, without being the first discoverer.

It is commonly believed that the discoverer of the possibility of educating the deaf-born was the French priest De l'Epee. But, that almost exclusively his name is connected with this discovery, is due only to the fact that he was the first who, in addition to instructing the deaf, also instructed those who were willing to become teachers of the deaf. And these teachers of the deaf carried the name of their teacher all over the world and made it famous.

The honor of the first discovery, so far as our present knowledge reaches, belongs to a Spanish Benedictine monk, Pedro Ponce, called de Leon, who died in 1584. How this discovery struck those contemporaries who in spite of the insufficient means of spreading ideas in those times heard of it, can be seen from the phrases used, in a book describing the totality of the work of the Benedictine order and published about 1600. "Our monk, fray Pedro Ponce de Leon," says the author, Antonio Perez, himself a Benedictine, "created that marvelous art of giving speech to the dumb. Thereby he has won the admiration of all who have heard of it, abroad as well as at home, on account of this wonderful display of genius. Yet he never succeeded in instructing others in the art. However, we know how much more difficult even than to practice oneself it is to train other masters in one's profession."

The honor of being the country of the second discovery of the art also belongs to Spain. And not only this, but also the honor of the publication of the first text-book for giving this instruction, and an elaborate and very suitable text-book, too. In the year 1620 appeared in Madrid the book by Juan Pablo Bonet whose title in literal translation is "Reduction of the letters,—and art of teaching the mute to speak." The book has been translated into English, French, and German. The rather curious title means that the author wants to make clear that the teacher of the dumb must himself begin with acquiring a knowledge of phonetics, because he has to teach his pupils the often varying sounds represented in script by each single letter of the alphabet. There can be no doubt that Bonet had heard it rumored that someone somewhere had succeeded somehow in teaching the dumb to speak. But he honestly rediscovered the method and rightfully claims the honor of his discovery. His first pupil was the brother of a nobleman, the Constable of Castile, whose secretary he was. The pupil had been deaf since the age of two years.

Bonet's book consists of two parts. The first part begins with the history of the art of writing and gives an exposition of phonetics, a little imperfect from the modern point of view, but nevertheless quite remarkable. The second part discusses the causes of mutism, the auxiliary use of the manual alphabet, lip reading, the formation of the separate sounds and their production in series. He gives a complete Spanish grammar adapted to the special needs of the deaf-mute pupil, and this part of the book is to be used as the regular text-book by the pupil as well as the teacher. The method is similar to that which goes nowadays under the name of the Berlitz method of teaching foreign languages. The text-book contains even a chapter on arithmetic.

Two further facts will be mentioned here in order to show how advanced the thought of Bonet was. He uses for the instruction of his pupils such modern aids as a flexible leather model of the tongue. And the modern educational psychologist reads with astonishment the following heading of the tenth chapter: "Reason why normal children are so slow in learning to read, and discovery that this is due to the difficulty which we create by teaching them the names of the letters first."

In the year 1622 another Spanish teacher of the deaf, Manuel Ramirez, became known and claimed for himself the discovery of the art of teaching the dumb to speak.

In 1657 Franciscus Mercurius van Helmont, son of the famous Flemish physician and chemist, published a book concerning the education of the deaf, but concerned himself only with lip reading.

In 1660 Wallis, a mathematician and also author of an English grammar which begins with an elaborate treatise on phonetics, thought that he was the first inventor of the art, having succeeded in teaching several deaf-mutes to speak.

In 1670 an Italian, Lana, claimed to be the first to have taught mutes to speak.

In 1690 the Swiss physician Amman, who spent the latter part of his life in Holland, had to treat a girl for deafness and succeeded in teaching her to speak. In 1692 he published a book "Surdus loquens" and, as usual in these cases, thought that he himself was the first inventor of the art.

In 1748 the Portuguese Pereira became famous in Paris as teacher of deaf-mutes. The history of his career is interesting. He happened to read in a book by the Benedictine monk Feyjoo a notice about Pedro Ponce. Thereupon

he tried to teach mutes, succeeded, and later was praised by many as the first discoverer of the art.

In 1761 Ernauld, of Bordeaux, presented to the French Academy of Sciences a communication in which he mentioned some previous teachers of deaf-mutes, but declared himself the inventor of a new method of teaching lip reading. He did not use a manual alphabet at all, but based his instruction on lip reading. This application of lip reading he regarded—and to a slight extent probably with justification—as his own contribution to the art of teaching the deaf.

De l'Epee published his book in 1776. He died in 1790. He was the first teacher of deaf-mutes who became the father of a training school for teachers of deaf-mutes. Several teachers trained by him established themselves successfully in Italy. Emperor Joseph II of Austria sent the Abbot Storch to Paris in order to import the methods of teaching the dumb into his dominions. Another author of much merit concerning this phase of education, Andres, in a letter written in 1794 to the wife of the Spanish ambassador in Vienna, characterizes the work of the French priest by calling it "unquestionably the most methodical and perfect," while upholding the priority claim of his countryman, Pedro Ponce.

A slightly prolonged occupation, like the one to which we have just submitted, with this matter helps to impress upon us the enormous significance for the "human intellect" of language, that is, of speech and script. Nothing can show this significance as clearly as the enthusiasm of those who by one accident or another were led to, and by patience succeeded in, teaching the dumb to speak, transforming as by a miracle animals into human beings. But on the other hand, it also impresses us with the enormous difficulty of convincing the great crowd of which humanity consists, that

herein lies the main difference between animal life and human life. "Do animals think?" is a question often asked. But few have always been those who could see that this was the same question as "Do animals speak?"

The art of teaching the dumb to speak, once discovered, ought to have spread thru the great crowd of humanity like a religious gospel. It ought to have become a commonplace at once, because of the psychological implication of the fact of human intelligence with this art. But the great crowd did not see the implication. The miraculous art satisfied the crowd's curiosity for a few years and was soon entirely forgotten, with the result that the art had to be rediscovered so many times. Even modern psychology, altho it has given considerable attention to language, is only slowly beginning to recognize that the "human intellect" is human language, that what is popularly called "mental" and popularly opposed to "physical or physiological," is merely that which in scientific psychology is found to be characterized by consisting mainly of language functions. Compare "memory" with "manual habits." In habits of "remembering" language functions prevail over the functions of other motor organs. That is the only difference.

We have above mentioned only incidentally the substitutes or surrogates for normal speech and script, invented for the use of those deprived of one or both of the higher senses. An introductory psychology is not the place to discuss details which are mainly of technological importance. Let us make only a few remarks about them. The manual alphabet serves as a surrogate for speech. But it is a visible kind of speech instead of an auditory one. It has all the general drawbacks of visual compared with audible signals. It can not rely, either, on the advantage of appealing to imitative reflexes, which is possessed by auditory stimulations. The execution of complex manual signals is,

further, very slow in comparison with the execution of signals by the vocal organs. Nevertheless, even the acquisition of nothing language-like but the "speech" by means of the manual alphabet will raise a dumb person above the level of an animal, give him a certain degree of human intelligence.

The raised script of the blind serves as a substitute for visible script. Its importance for the intellect of the blind, however, is only relative, since the blind, possessing speech, possess thereby also the use of generalization and abstraction without being taught to read and write raised script. The intellectual level of an uneducated blind-born person is essentially the same as that of an uneducated normal person, whereas the uneducated deaf-born person, as we have seen, is comparable to an animal.

Most difficult, naturally, is the education of those who have lost both the higher senses at birth or not much later. In these cases signaling is possible only by appealing to the sense of touch. The first speech surrogate therefore is based on writing a short word with one's finger on the palm of the hand of the person to be educated and inducing him (since the "localizing reflex" causes him to imitate the stimulation only with remote exactness) to imitate by writing thru habit on his hand the same word with his own finger. Later the process of education becomes more similar to that of the dumb. To what height one can develop the intellect even of a person who has lacked virtually from birth both sight and hearing, is illustrated by the example of our countrywoman Helen Keller, who has become famous even as an author.

In this connection it is well to point out why the senses of sight and hearing, to which we have repeatedly referred as the "higher senses," deserve this name. It is not that these sense organs or their functions have any property

which elevates them physically, chemically, or biologically above the other senses. They are rather those senses which can be spared most readily without destroying the possibility of life. They are higher only in the sense that the particular feature distinguishing man from animals, the human intellect, that is, the nervous function of generalization and abstraction, is by far more dependent on the function of the organs of sight and hearing than on that of the other sense organs. But even this dependence is not absolute, since the intellect can be developed, by the invention and application of the proper kind of educational art, even in those who lack these two senses.

The higher senses, then, are simply those senses on which the development of the intellect depends in the natural and usual course of events. These are the senses which mankind particularly needs for "being thoughtful."

CHAPTER XVIII

The Other-One Walks in his Sleep. Disturbances of Personality. Abnormalities.

There are variations in the Other-One's customary mode of reacting to stimuli which belong to a class different from that of willing and learning. They are technically called "symptoms of neurosis." That is, they are abnormal. They result from an abnormal or diseased condition of the nervous system. Our chief interest in abnormalities lies in the fact that they may illustrate some of the normal functions hitherto discussed in so striking a manner that examples from the behavior of the Other-One, as he normally stands before us, are not of equal illustrative value.

The layman thinks, when he thinks of psychological abnormalities, first and mainly of the "somnambulist," in literal translation, sleep-walker. The somnambulist is popularly supposed to have been disturbed in his sleep by the moon. Therefore he is also called a "lunatic." And institutions for the confinement and treatment of people suffering from nervous diseases are in some regions even officially still called "lunatic asylums." A most perfect sample description of the symptoms of a certain type of nervous disease is found in Shakespeare's "Macbeth."

"Since his majesty went into the field," the gentlewoman reports to the doctor, "I have seen her rise from her bed, throw her nightgown upon her, unlock her closet, take forth paper, fold it, write upon't, read it, afterwards seal it, and again return to bed; yet all this while in a most fast sleep."—Shakespeare here gives us in the gentlewoman's talk an exact sample of the popular attitude in a case like

this. The uncritical observer of the somnambulist always exaggerates when he tells what he observed. "She is in a most fast sleep." As a matter of fact, we do not call that sleep when the Other-One is so active as one is in writing and sealing letters. What the gentlewoman really ought to say in accordance with the truth would be something more moderate, like this: "Considering that we regard almost everybody at that time of the night as asleep unless he is dressed for and doing special night duty, as a watchman's; and considering further that a minute before writing she actually was in bed and a few minutes later she was in bed again; and considering that she did not say to me 'How do you do,' as she does when she meets me ordinarily, but passed me as if I were a wooden pillar; and considering that she treats us (speaking to the doctor) just now with the same slight attention; and considering that she talks now before us of such suspicious things as the spots on her hands, and of the unexpectedly large quantity of blood which the old man had, and that she rubs her hands as if they needed a cleaning—I should say that she was not then and is not now exactly what one would call 'awake to the situation.' If we were her enemies, she would already have given herself away."

In the popular (not recognizable as scientific) psychology sleep is not a purely relative amount of being active, or rather of being inactive, but is a specific "state of the soul." To the "popular" psychologist the most curious fact then seems to be that here a "soul" is found to be "not fully awake" or "asleep" or "subconscious" in a body which is not lying in bed, but standing up and even walking about. Therefore "somnambulism."

To the psychologist who is a man of science it makes no great difference whether you call that observation sleep or, better, relative inactivity, or give it no name at all. All

that interests him is the fact that the Other-One's reactions observed are reactions very unusual in such a situation.

Usually a person who has his eyes open says "How do you do" when entering a room in which there are acquaintances. Lady Macbeth, altho her eyes are open, addresses her acquaintances no more that she would address a piece of furniture. A murderer fearing discovery of his deed ordinarily abstains from loud comments on the quantity of blood of his victim. Lady Macbeth makes such remarks in the presence of others. What the psychologist observes is that the stimuli are not adequate to the reactions, that the reactions are those which one would expect of Lady Macbeth only in an entirely different situation. We have, therefore, a case perfectly similar to that in a previous chapter where a man stands still on a busy street where everybody walks, and answers the traffic policeman "It's your move." Lady Macbeth is obviously "preoccupied."

But the difference between her preoccupation and that which occurs in a normal person—as in that chess enthusiast—consists in the fact that normal preoccupation rarely lasts more than a few minutes, in exceedingly rare cases (where it becomes a "joke") as long as a few hours. But in a case like that of Lady Macbeth, in a neurosis, the preoccupation lasts days, weeks, or months, and even years. In saying that it lasts so long we do not wish to be understood as meaning that it lasts in unvarying strength. There may be ups and downs in that preoccupation. Nevertheless, it often seems to be the same preoccupation after weeks or months, having fluctuated meanwhile, but without having been clearly interrupted and fortuitously recreated.

If we hold the contact improvement in the synapses of any higher centers responsible for any symptoms of preoccupation, it follows that these neuron terminals must have

in these abnormal cases an inherited tendency to "stick" after having extended in consequence of a nervous flux passing thru them. Normally they would recede within a few seconds or minutes after the cessation of the nervous currents. These neurons in the case of this neurosis seem to have lost this ability to recede again. The consequence is that, whatever nervous current passes thru the nervous system, finds thru these synapses a path more conductive than it ought to be. The result is that certain reactions occur with a frequency out of proportion to their probability as reflexes or established habits.

One naturally asks, then, "Is this loss of ability on the part of neurons to withdraw their terminal branches after cessation of the flux with the normal speed, restricted in the individual to a particular nerve center?" The clinical observations show that it is not so restricted, but that this is an abnormal property of all the higher centers. The particular kind of preoccupation, like "talking of blood and wiping the hands," depends merely on circumstances (of specially effective stimulation applied under specially favorable conditions of the organism). Under other circumstances establishing a preoccupation of this patient other reactions would have appeared as the symptoms. But the tendency toward abnormal preoccupation is a general tendency of the nervous system belonging to that individual. Making use of the ancient term "hysteria" (very absurd in its literal meaning, which is womb trouble), this neurosis is often pronounced to be a "tendency toward hysterical symptoms." It is actually as common in men as in women.

Examples of the clinical observations referred to in the preceding paragraph are the following, reported by the French psychologist Pierre Janet, to whom we owe the most elucidating studies of this matter. A lady forty-three years old has terrible fits in which convulsions and howlings

mingle together for fifteen or twenty hours as a reaction to such simple stimulations as the mentioning of a calendar date before her, as the pronunciation of the words "love," "affection," "happiness," as a dog barking on the street, the sight of a cat passing by on the street, the pronunciation of the words "dog" and "cat," and many others to which no normal person would respond by convulsions and howlings. It all becomes plausible when we know her history, in which a certain event occurred in which stimuli of this very kind belonged to a total situation calling forth a mixture of extreme disappointment and anger with fate, thus establishing preoccupation in a particular sensory-motor direction. A dear friend had died. Only one souvenir from him, an old dog, remained. Then the dog died, in his turn, on a carpet. And the lady lay down on the carpet on which the dog had died, and remained there for sixty days without consenting to sit at table for a meal or to take the usual care of herself. The case is essentially the same as that of the chess player, an extraordinary readiness for a certain kind of sensory-motor function. Only every aspect of it is more extreme.

In another patient the reactions and the stimuli differ, not because the tendency toward preoccupation is a different one by heredity, but because the life history is a different one. The sight of a flame, sometimes of a match only, brings about a particular fit in a patient who has been affected by a conflagration. And, as the peculiar power of a special stimulus, so the nature of the reaction, altho first seeming entirely irrational, explains itself as soon as the patient's life history is known. "There's method" in what seemed irrational madness. A patient presents an intense tremor of the right hand. It is finally discovered that the tremor started from a long continued practice in so-called automatic writing in order to question spirits. The tremor

is nothing but the quick execution of writing movements. Put a pencil in the patient's right hand, and the tremor is transformed into writing. If the policeman had asked the chess enthusiast for a match, or for the time, there would probably have been no occasion for a joke, because there would have been no occasion for "method in madness."

A patient in her nocturnal somnambulism makes a peculiar movement up and down with her foot, makes also a turning movement at her right wrist and simultaneously says all the time: "I must work, I must work."—One evening, as a girl of sixteen, she had heard her parents bewail their poverty. She was very much moved, and from that time had at night her "somnambulism." The trade of the girl was that of making doll's eyes, and, for this purpose, she worked a lathe by treading a pedal with her foot and turning a fly-wheel with her right hand. If she had only tossed in bed as we all do now and then, we would not call it somnambulism. But our tossing is neither more nor less mysterious. Only our tossing would not illustrate such an extreme case of preoccupation.

A man is paralyzed on his left side. He explains it as caused by a tremendous shock. But the real explanation is abnormally extended preoccupation, for which his nervous system certainly had a congenital predisposition. Traveling by rail he had done an imprudent thing: while the train was running, he had gotten down on the outer step. At that moment he became aware that the train was about to enter a tunnel. It occurred to him that his left side, which projected, was going to be knocked and crushed against the tunnel. He swooned away, but happily at that moment was pulled back by others into the carriage. His left side was not even grazed. Nevertheless, the muscles on that side no longer contracted. The preoccupation here obviously consisted in the synapses leading every nervous

current which normally would reach those muscles, into a certain high nerve center whence it could further distribute itself in almost any motor direction rather than into the "paralyzed" muscles.

That the congenital tendency of certain people to suffer from preoccupation of an abnormal character exists in their whole nervous system and is not merely a tendency confined to a part of the nervous system, is proved by other facts than the definite relation found between the special sensory-motor disturbance and the fortuitous life history of each patient. It is also proved by the transferability or transmutability of the symptom. It is often easy, thru some psychological process or other, to cause such or such a determinate symptom to disappear. Besides, the symptom often disappears of itself, in consequence of an emotion, of some surprise, or even without reason. But when a symptom has disappeared, especially when it has disappeared too quickly, another neurotic symptom often takes the place of the first. The patient is "cured" of vomiting and now suffers from delirium. He had a contracture in the neck, a stiff neck, and now has a contracture in one hand. A man had hysterical coughing and now has crises of sleep, sleeps a week or longer continuously. A man had a foot contractured and was cured thru a somewhat mysterious process which frightened him. He now can walk freely, but has lost his voice. When, after three months, his voice returns, he has stomach trouble and abdominal contractures. Another man had contractures of the trunk and now, being cured of the first trouble, no longer responds to anything acting on his eyes,—he is virtually blind.

All this is comprehensible. There are several "preoccupations," but owing to the law of "deflection," which is effective in the neurotic as in the normal person, the nervous current which happens to be strong, prevents the other

currents from reaching any considerable strength of flux and thus keeps the other "preoccupations" from developing for the present to any conspicuous height. Any preoccupation is anyway, as we pointed out, nothing constant, but is fluctuating in strength, in these abnormal as in normal cases. But as soon as any particular form of the patient's preoccupation goes down in strength, there is no longer that deflecting current, and another particular preoccupation has a chance to develop to great height.

But, when we say that this abnormal tendency for the terminal branches in a synapse to "stick" after having extended, affects the whole nervous system of the neurotic patient, we do not after all mean exactly the whole nervous system. There are undoubtedly differences between the lower and the higher centers. We have already pointed out, in speaking of normal preoccupation (absent-mindedness, as we also called it), that it is not easily observed in those who do merely routine work consisting of reflex-like habits. At least, it never lasts in them more than a few seconds. For the very same reason as in those normal cases, in these neurotic cases where there is abnormal preoccupation, the troublesome symptoms occur in the habit functions only, and with the most pronounced frequency in the very highest habit functions. The reflexes are virtually free from these troubles, and the more so, the more they have preserved their original character as reflexes, the less they have become dependent on higher nerve centers.

Among the most extreme examples illustrating that the very highest centers are those where preoccupation most readily plays its role, are those where "abstractions" make up the main part of the nervous function. Invite the Other-One to do something, to raise a hand, to step forward, or anything much more complex, if you wish. If you succeed, by talking to him convincingly (which may

or may not be easy), in stimulating in him the nervous function which, for want of a briefer name, we call the "abstract idea that this is necessary for his religious salvation," you will be surprised how quickly he carries out your request that he raise his hand. If, on the other hand, you convince him of the abstract idea "that there is no such thing as a hand," you will be surprized with what an absolutely negative smile he will refrain from raising his hand at your request, which then would be senseless. Every nervous process would be side-tracked, so to speak, away from the hand muscles.

So it happens that a patient may be preoccupied with the abstraction "there is no such thing as whistling on *my* part." You then observe—and such cases are not rare—that your patient can eat, drink, speak, pout, spit, and what not, with his lips, but he can no longer whistle with them altho he used to do it formerly. Or, in a similar case, a patient, while lying in bed, can raise his legs, bend them, turn them, can push your hands back with his feet, can lift you up if you bear down with all your strength on his knees. But put him on his feet and ask him to stand or walk,—and he collapses. His legs are completely "paralyzed." He is preoccupied with the abstraction "there is no such thing as walking on *my* part."

Reflexes, however, are the less interfered with, the less they have become modified into habits. For example, the application of a little ice on the patient's fore-arm brings about the usual reflex response, the immediate contraction of all the vessels of the hand. This has never been modified into a habit. But the neurotic patient, altho perfectly friendly toward you and convinced of your best intentions and his own indebtedness to your kindness, may entirely fail to respond to your request to make a sign by words or motions as soon as you, having blind-folded him, place a

little ice on his fore-arm. He is there "anesthetic" so far as his habits are concerned, but not with reference to pure reflexes. Preoccupation, that is, the synaptic condition meant, does not easily occur in these pure reflex paths, in the lowest centers.

Certain muscles, then, as well as certain sense organs still are in the service of the reflexes, while the same sense organs or muscles may no longer be in the service of many, most, or perhaps virtually all habits, because they have been enslaved by a few abstractions. For this reason further facts become clear which would otherwise surprise us. Neurotics of the kind under discussion do not suffer any deterioration of their muscles in consequence of paralysis. This deterioration is a serious matter in the case of paralysis caused by a lesion within the nervous system. The paralyzed muscles, never contracting, gradually shrink, are absorbed, and if the nervous lesion is cured after months or years, it little helps the patient who has lost the muscles needed. Most tragical are such occurrences in children having suffered from infantile paralysis, a disease which destroys whole bundles of neurons. The unfortunate patients, still in their period of growth, thru the indirect consequences of the nervous lesion often become cripples for life.

No shrinkage of the "paralyzed" muscles occurs in these neurotics. There is enough muscular contraction—tho too weak to be observed or not observed because occurring during the night—to prevent the deterioration of the muscles. The muscles are still in the service of the purer, little modified, reflexes.

Anesthesia, too, in all sense organs, when due to a nervous lesion, has its serious indirect consequences. For example, if the limb of an animal is made anesthetic by cutting certain nerves, this limb, quite intact at first, can not

be preserved. It is not long in becoming covered with sores, and little by little the animal itself bites it off. There are patients who complain that their hands are constantly burned or wounded. They are not able to avoid injuries. They have a spinal lesion which makes them insensible to cold and heat. Where the "anesthesia" is merely a symptom of abnormal preoccupation, such indirect troubles are not likely to occur. The reflexes still protect the patients to a high degree.

The difference between reflexes and habits—the functioning of lower and higher centers—may lead to consequences very ridiculous or very tragical according to the circumstances and the ability of those dealing with the patient to understand his case. Take the following example. A patient is anesthetic (thru preoccupation) on one side and has normal sensibility on the other. We blind-fold him and pinch him on one side, and he tells us where we pinched him. We pinch him on the other side, and he does not tell us where we pinched him. But since his original reflexes are not destroyed, we can build up a new habit,—and perhaps thru the medium of higher centers which happen to be little affected by the existing preoccupation. We request him, we persuade him, to say "Yes" when he feels and to say "No" when he does not feel. This is a habit formation, but of the kind of "quick learning" which we call "willing." If the patient is a little simple minded, not intellectual, we succeed. The new habit happens to be free from the interference of the preoccupation; and whenever we touch the "anesthetic" side, the patient says "No."

The observer ignorant of psychology will then show little patience with that patient. "He is no patient at all," he will say, "he is an habitual liar or pretender. A person who tells us that he feels nothing when he is pinched on a certain spot and yet says "No" in response to being pinched.

while blind-folded, on that spot, is a person who lies to us." The non-psychologist does not understand that these are two different habits, of which one may well suffer from the preoccupation of the patient and the other not. Of course, in a person of high intellect the whole experiment is not likely to succeed, or is likely to succeed only a short time, since the new habit will quickly fuse with the old habit. The intellectual person "will see the nonsense of the request." But what succeeds in others, may succeed in him if the conditions become more complex. All thru the history of medicine the accusation goes that hystericals are habitual liars. An hysterical person may be a liar just as a non-hysterical person may be a liar. But he should not be regarded as a liar because he is hysterical and ought not to suffer the moral contempt of others on account of being ill. Tragical illustrations belonging to the same category are plentiful in the application of the criminal law, if one studies the history of the criminal law from this point of view.

The case of insufficient condensation previously discussed in the case of discrimination on the skin can be referred to here. We would object if someone would call us a liar because we say that what he placed on our skin "feels like one point and yet feels like two," as subjects not infrequently are heard to say in such an experiment.

We have pointed out in a previous chapter certain other laboratory experiments in which we tend to react unreasonably. In stereoscopic vision we may say, "I see two pencils and I also see that the pencil is farther than the finger." We would object if someone would tell us: "You are a liar, for seeing the greater distance of the pencil is a substitute for seeing it double. You can not see the replacing thing and the replaced thing at the same time."

In the same previous chapter we mentioned one further reason (among innumerable actual reasons) why hysterical patients are exposed to being wrongly regarded as insincere. In that former case the trouble was due to failure of the eyes to move as incessantly as they normally do. Such failure may result from drugs. The "double vision" of the alcohol intoxicated person is proverbial. But stiffness of limbs or organs, "contractures," have been mentioned as common symptoms of the neurosis of preoccupation. If the eyes are motionless from the latter cause, such troubles as those just mentioned become a reality. Another result of lack of motion of the eyes deserves to be mentioned in this connection. The somnambulistic, hysterical, patient often tells us that he sees people surrounded by an "aura" or that he sees ghosts. We can see the aura too if we stare at a person long enough; but it is difficult for a normal person to do that. These are nothing but unintended and uncomprehended experiments, made by ignorant people, in simultaneous and successive visual induction..

We owe it to Janet more than to anyone else to have made it clear that the state of hypnosis is nothing but a state of abnormal preoccupation like those described above, only artificially and intentionally produced instead of resulting from an accident in life. As is to be expected, people differ greatly in the ease with which they can be hypnotized. Some have a nervous system whose synapses greatly predispose the owner to becoming preoccupied with affairs of little intellectual significance. We then call them hypnotized or hysterical. If their affair is a highly intellectual one (think of the "absent-minded professor") and the preoccupation results from intense normal work and not from a congenitally abnormal nervous system, we do not call them either hypnotized or hysterical. But the cases are essentially the same.

The physician Robert Mayer, famous in the history of science, ran into a friend's house without knocking at the door, exclaimed "It is true, it is true," and would not listen to anything for a long time. His friend thought that Mayer had gone insane; he had entirely forgotten that many weeks before they had discussed the question whether water in a bottle could be warmed by merely shaking the bottle, and that he himself had rejected that idea as absurd. But Mayer continued to be occupied by that same question.

Any change in the Other-One's habits may be called a change in the Other-One's personality. The reaction after every process of willing or learning is a symptom of a change in his personality. Where the change of habit is profound and abnormal, we speak of a disturbance of the personality; even of the splitting of a personality in those cases where the change periodically recurs. But there is no essential difference between the most astonishing splitting of a personality and the simplest hypnotic or somnambulistic performance. And in the description of all these cases such terms as the "division of a soul" into parts, a "conscious," a "subsconscious," a "coconscious," etc., one, are better avoided. That such terms are so popular, is, of course, due to the fact that even those people are able to use them glibly in their speech who have never devoted time and energy to a serious study of those problems of human behavior which fall within the province of the natural sciences.

Abnormal nervous functions of any kind interest us in an introductory text-book of psychology only in so far as they illustrate the normal anatomical and physiological properties of the nervous system. That property of the synapse which leads to preoccupation has already been illustrated by abnormalities. The other normal anatomical and physiological properties of the nervous system are not so

strikingly illustrated by abnormalities and there is, therefore, less reason for discussing the other abnormalities. It is worth while, nevertheless, to enumerate again all the various anatomical and physiological properties of the nervous system which form the basis of the systematic description in this book of the Other-One's life activities, and to point out what abnormalities may result from them in consequence of bad heredity or of pathological conditions arising during life.

It is not to be expected that a being born with an anatomical deficiency of reflex paths would live long. That anatomical possibility, therefore, need not concern us psychologists much. But a human being may be born with a deficiency in its possible equipment with higher centers and continue to live. Indeed, we are, perhaps, all born with such a deficiency. The result may be either the one or the other or both of the two abnormalities mentioned presently, which are so common that we simply call them individual differences.

Higher centers have a great importance for the concertedness of the functioning of certain reflexes. We gave these concerted reflexes the name of instincts. A congenital deficiency in a person's equipment with higher centers in a certain region of the brain might thus be regarded as the cause of a weakness of certain instincts which in other individuals may be strong. But let us remember that the concertedness of most human actions is not congenital at all, but acquired during life.

We remember, secondly, that in order to acquire a particular habit, we must first of all have that particular "long path." In the reduction of the resistance of that path consists the formation of that habit. Now, we know that one person acquires easily only these habits, another person easily only those habits. The chief source of the individual

difference is undoubtedly the congenital anatomical difference. If the Other-One's nerve centers in those regions in which the reflexes in question have their paths, are only poorly equipped with long paths, then those particular reflexes can be modified into habits only with difficulty, that is, thru mediation of long paths too long in the first instance. That must be one of the chief causes of individual differences.

The person who is born with a general deficiency in his equipment with higher centers, the microcephalic person, for example, who has very little brain substance, is a born idiot. But we are all of us in a relative sense born idiots. There are sensory-motor functions which we can not easily acquire in perfection, tho we see some others succeed in them.

Very important for acquiring and retaining habits is the degree of the positive and of the negative susceptibility of the neurons. There are undoubtedly great congenital differences in this respect between individuals. Some persons learn everything that they learn at all, very quickly. Others learn slowly, needing more repetitions. But one must not think in connection with the speed of learning that, whenever a person learns something slowly, the susceptibility of his neurons is small. He may learn slowly because he "understands" slowly, because he lacks a good anatomical equipment of certain higher centers especially implicated and has to rely on very indirect "long" (too long) paths. The greatest difficulty in interpreting the results of experiments in human or animal behavior results from the fact that they rarely are based (perhaps rarely can be based) on a preliminary analysis of the nervous functions involved. It is clear that an observed speed of learning, for example, may be the outward sign of any one or more of several properties of the nervous system.

We saw that deflection is a very important nervous function. But it does not seem plausible that deflection as such, in general, can be stronger in one individual than in another. Indirectly, thru anatomical causes, deflection among particular nervous currents may be weak in a particular person, because there can be no deflection without a certain "contact" or relatively close, not too indirect, connection of the paths of the current to be deflected and the deflecting current.

With respect to shortening a long path after its resistance has been reduced, there is a possibility of congenital individual differences. Unless the individual has undeveloped neurons existing in the region where a short-circuiting might occur, no shortening of the path is possible.

We were discussing disturbances of the personality and now return briefly to that problem. We must ask, now, what influences occurring during life might change a person in the same or a similar way as a different constitutional inheritance would have made him a different person.

With reference to the synapse, it seems that great nervous fatigue and also certain drugs aggravate a natural predisposition for abnormal preoccupation. Hysterical symptoms and a changed personality often make their first appearance after exhaustion or intoxication.

Anatomical interferences are easily understood. A wound, say, the passing of a bullet thru the head, or an inflammatory disease, or a breaking down of some (not necessarily all or most) cells thru age, may completely destroy certain nervous paths. The effect is, of course, then of the same kind as if it were an inborn anatomical deficiency. An individual may not be originally, but may become at a certain time in his life, idiotic, demented, in a more or less relative sense. If we can still notice that he formerly acquired an "intellect," but that that acquisition no longer

functions properly, it is customary to say that he has "paranoia," that "his reason goes astray."

On the other hand, an inflammatory disease, or natural old age decay, or a poison created somewhere in a diseased part of the body and carried by the blood thru the nervous system, or a drug taken into the body and acting on the nervous system, may not destroy the substance of the neurons, but may alter them so that they may gain or lose, permanently or temporarily, in conductivity; or so that they lose all or much of their susceptibility, or, maybe, have more of it. Particular disturbances of the personality of the individual must result. The change in conductivity must make certain reactions uncommonly frequent and strong, or uncommonly rare and weak. This may occur alternately, as in manic-depressive insanity. The change in susceptibility must make the individual quicker or slower in "learning" and "willing."

Epilepsy, which in its extreme form shows itself in convulsions, may be an abnormal general conductivity of the nervous tissue, breaking forth momentarily and subsiding again quickly. Instead of this or that muscle contracting, all contract in an extreme degree for the time being.

Disturbances of personality interest us especially as illustrating normal nervous properties and functions. But they can themselves be understood only if one has a clear idea of the normal function of the nervous system in the whole living body. Otherwise abnormal psychology is a mere collection of curiosities.

CHAPTER XIX

The Psychology of the Other-One and the Sciences Other than Psychology.

Science is one, intrinsically undividable, whole. That is, all divisions of it are arbitrary, fortuitous, due to the limitations of one person's energy and interest. The man of science who is asked to define a particular science and justify its separation, never feels satisfied with his own answer.

When a university man and a man engaged in a trade or business who perhaps has never attended the high school happen to get acquainted on the street, in a store, in a railroad car or a similar place, the question is usually asked: "What do you teach?" And after the teacher has answered it, the next, almost inevitable, question is: "What is that?" And then we have to give an answer which we really disapprove of and even feel ashamed of because we know that it is unclear. But we give it nevertheless because we know that a clear answer would be a whole college course; and evading the answer altogether would seem discourteous. So we speak out.

"All about the earth," says the geologist. "All about sound and light and electricity," says the physicist. "All about animals and plants," the biologist. "All about the soul," the psychologist. What else could he say in that situation?

What troubles the psychologist in giving the answer is this, that he is really in no more special manner interested in the soul than other people who are not psychologists.

But what can he do when he has to give a brief answer? It does not help him if, instead of "All about the soul" he says: "I teach all about the mind." The majority of modern progressive psychologists would deny that as psychologists they are particularly interested in the mind, in mentality, in consciousness, or whatever synonym of "soul" you choose. That period in the history of psychology, when those terms stood in the center of discussion, is passing away, never to return.

In recent years men have lamented (using an expression which sounds like a joke, but is meant as a serious complaint) that psychology has "lost its mind." Just as a funeral oration is fair testimony that the man in whose honor it is spoken is dead, so this complaint is fair testimony that psychologists are no longer concerned, chiefly, with the mind.

It is a curious fact that what is nowadays technically called psychological, would appear often in the language of a hundred years ago the very opposite, the unpsychological. Inasmuch as we all, even the professional psychologists themselves, still live in the general literary atmosphere of our ancestors of a hundred, and even hundreds, of years ago, a discussion of the fact stated in the preceding sentence is desirable.

The old, and still popularly accepted, meaning of the word "psychological" is derived from the literal meaning of the Greek word "psyche," that is, soul. Unless you can or will mention a soul, you would then not consider the matter as "psychological." Out of such general questions arise in many instances specialized questions which thruout the history of mankind have puzzled the lawyers and the legislators, and naturally even more the theologians,—such questions as this, whether the unborn child has a soul, or whether the "infant," the not yet speaking, child has a

soul. Think, for example, of the untold misery that has been brought over countless human beings by answering in the one rather than in the other way the question, whether the mother drowning her newborn baby has committed murder of another soul or a partial suicide of her own soul or neither. Or the question whether the unbaptized soul of the infant goes to hell, an impossibility in case the infant has no soul yet. We are beginning to think more and more lightly of questions like these, which were a heavy burden to the conscience of our ancestors. How has this change come about, in popular thinking, and even more pronouncedly in the thought of men of science?

History is one of the social sciences. To the naive thinker, however, history is the science which records the deeds of individual great men. History is then chiefly a record of the deeds of heroes, of prophets, of kings. Remove Achilles, Agamemnon, and the other names of heroes from the Iliad. What would be left? Remove the name of Christ from the history of the Church. What would be left? To the naive thinker history is the product of the whirling processes going on in the individual great soul. Human society is both the clay which is being moulded by such a soul and the tool by means of which the particles of that clay are pushed forward by that great soul. The only really interesting thing is the great soul that does it.

It used to be customary to refer to the view opposing this naive one by the curious phrase of a materialistic view of history. This, however, is only an example of what we find to be generally true: the modern psychological view in every one of its applications has had to submit to being branded, sometimes by friends, sometimes by foes, as the materialistic, that is, seemingly, the entirely unpsychological view of humanity. There are many reasons for this misbranding.

For example, it was concluded that the world, if it was not controlled by souls, must be controlled by the stomach and sex organs, by hunger and love, as Goethe said in a little poem, and that the complete development of this principle would lead to the glorification of riotous living and self-indulgence. As a matter of fact, the materialistic view of history is, or should be, something very different. It simply regards history as the mutual reaction of groups of organisms,—organisms which are equipped by Nature, not only with digesting and propagating functions, but with equally fundamental altruistic functions. These latter functions—call them reflexes, instincts, or what not—establish the very grouping of the organisms. Human societies can thus be understood as originating from natural laws,—not in the sense of groups of souls tho, but in the sense of groups of organisms. Accepting this view, we readily understand why the trend of history is in the direction of democracy.

Let souls (of which we never experience any but our own) be as different in degree and kind as a despotic monarch is apt to imagine them to be. Human organisms—that we know by experience and therefore cannot imagine otherwise—have more likenesses than differences. The proof is easy. Fill a museum of human life with the specimens of the human race that are for all practical purposes alike. You cannot do it. No museum would be large enough. But you can place in a museum, for comparison, a Darwin and an idiot, or a man seven feet tall and a negrito four feet tall. It is the differences which we exhibit in museums because the differences are rare. In real world-wide human life the differences among individuals are entirely swamped by their likenesses. To him who accepts the scientific view that human society is a group of organisms, it is an absurd proposition to divide even as small a group as, say, a hundred into only two classes, placing ninety-nine in the one,

the subjected class, and a single member in the other, the governing class. No considerable number of individual organisms can ever live depending on the accidents of the life of one. With souls that may be different; but in science souls no longer play their former role.

We spoke of history. Let us speak of other social sciences. Modern criminology would never have come into existence if our psychological thinking had not passed from its former stage, during which mankind's very proper interest in Man was mainly an interest in his soul, to the modern stage where our psychological interest turns to the functioning of man as an organism. The old-fashioned idea of a crime is that of an interference with one soul's independence by another soul. The proper punishment then consists in pushing the latter soul as far to starboard as it arbitrarily pushed the former to larboard. Thus the balance of the spiritual world would have been re-established. That it was the only purpose of punishment to set the world right again in this almost mathematically exact manner by spiritual mechanics, the writer was taught in his student days by a professor of philosophy who called himself proudly the last Hegelian. Modern criminology, however, adopting the modern psychological way of thinking of man as an organism, not as a soul, regards a crime as a case of poor adjustment of one organism to the others and also—not less—of the other organisms to the one, and punishment as one of the means of improving this biological adjustment.

All the social sciences will have to take the same road. Economics has one foot already on it, but it seems to have the other foot still on the old road forming an endless circle which leads nowhere. We still see too much interest shown among economists in speculative discussions of subjective terms, such as "value," which in no way contribute to the

real problem of finding how human organisms produce, accumulate, and distribute things which help to strengthen the functions of these organisms.

Sociology, that is, the mass of knowledge of a social kind to which we apply the term "sociology" in the restricted sense, perhaps has had unusually good luck. Coming into existence rather late, let us say during the last fifty years, it seems always to have had the advantage of the pressure resulting from the immediate social needs of mankind. Sociologists, that is, have always felt so strongly the need of social reform, the need of betterment of the lives of the very organisms with whom they rubbed shoulders in the crowd on the street, that they did not find much time for talk about souls. Nevertheless there are sociological books whose very chapter headings make one shudder, so far removed are they from the warmth of life,—such headings as "Intuitive Perception," "Intuitive Reason," or "Female Intuition." That is Hegel revived.

A further social science is the science of religion, or, as it is often called, the psychology of religion. Who doubts that religion is one of the strongest forces in society? And yet, for thousands of years the intellectual interest of men, of students, has been restricted to the unsocial, artificial problems of religion, the questions as to the interrelation of souls,—for example, the question how one soul may contribute to the eternal salvation or eternal damnation of other souls, briefly speaking, to theology, which is not a social, but a purely individualistic affair, one intellectual game among the many which fill the history of philosophy.

The modern psychological way of thinking has brought us back to the solid ground of appreciating religion as a social phenomenon, exemplified by Christ going among his fellow men, an organism among organisms, and comforting and encouraging those whose burdens in society were

heaviest, making it easier for them to carry the burden when its removal under the existing conditions was impossible.

It is easy enough, then, to answer the question what use the social sciences have for psychology. They simply are psychology in the modern sense of the word; and on the other hand, psychology is social science.

We psychologists must often hear the (unjustified) reproach that our psychology is nothing but physiology or neurology or some similar "unpsychological," materialistic science, against which you would better protect the unsuspecting, pure soul of the college freshman. But we psychologists have no difficulty in distinguishing our interests from those of other biological departments. We study the organism as an organism, it is true, but only in so far as its functions have distinctly social significance. We do not study the stomach, because its function is an individualistic affair with which society is not directly concerned. It is the physiologist's business. We do not study the breakdown of nerve cells under the influence of excessive athletic training. That is an individualistic affair, the business of the medical man. But we are concerned with the possibilities of developing habits and with the limitations, if there are any, which Nature may have placed upon the development of habits. We are convinced that habits are the mysterious entities so much and so vaguely talked about under the name of social forces.

A hundred years ago Johannes Mueller, the father of modern physiology, made the famous remark: Nemo psychologus nisi physiologus." That was a valuable statement at his time when psychology was still mixed up with speculative philosophy and very little psychology in the modern sense existed. Today a still more valuable statement would be this: "Nemo psychologus nisi sociologus."

The psychologist, however up-to-date, is not a materialist. He does not deny the existence of the soul. He may deny, however, that it is his business to waste his time in trying to make the soul an object of scientific inquiry. We do not deny the soul; but we do not devote our time to it. We find enough, and more than enough, to do studying the body. For instance, when we study memory, we do not study the soul. We find out, for example, how many times the speech organs have to pronounce a series of words placed before the eye until they will pronounce the whole series correctly with only the first word appearing before the eye. That is a study of the organic functioning of the body.

It is unfortunate that no human being can be always safe and sane in his ways of thinking. Even if I could master all the scientific achievements of the day, which obviously one individual can not, these scientific achievements themselves are only a small part of that complete understanding of the world which a divine being would possess. Owing to the individual and general limitation of scientific knowledge, moments arise in everyone's life, less frequently in one's, more frequently in another's, when no amount of rational thought, but faith in the destiny of this world, religious faith alone can give him comfort. Religion is needed, then and therefore. But remember, it is extra-scientific.

Now you will perhaps ask: If psychology is not the science of the soul, but one of the many sciences of material bodies, will it always be possible to define it so that I can distinguish it from the other sciences? The answer is simple. Don't distinguish it. Don't define it. You don't have to define it any more than you have to define physics. That is physics in which those are interested who are called physicists by consensus of opinion. For the purposes of mankind that is not only a sufficient, but a better definition

than any more detailed one you might substitute. We have hinted, in the first chapter and in this chapter, at a definition of psychology in terms describing its subject matter. But really the best definition, the one that serves human society best, is this: Psychology is that in which psychologists are interested as men of science.

This definition has also this great advantage for the psychologist that now the other sciences can no longer unload their unsolved problems on psychology by shrugging their shoulders, so to speak, and saying: Here is a problem whose solution concerns us,—concerns us more than anyone else. But it seems to be a problem of the soul, therefore we must wait until the psychologists solve it.

You see how hopeless the case then would be. If it is a problem of the soul, then it is no scientific problem at all and the psychologist will never pay any attention to it. But if it is an objective problem, a real problem, then it is a problem of that science which is directly concerned with it.

If the lawyer has a problem, and if no one else cares for it enough to attempt its solution, then it is a lawyer's problem, a problem of jurisprudence; and it is primarily the lawyer's business to solve it. Don't be lazy and call it a psychological problem.

If the engineer has a problem, say, whether the man in the locomotive cab should wear overalls or an apron, don't be lazy and call it a psychological problem. If no psychologist and nobody else can be made to take an interest in the question but you, then it is a problem in engineering.

If the economist has a problem, say, why people want to buy things that they have no use for, don't say: "Excuse me, this is psychology. It is a problem of the soul. It is mysterious. We can't solve it. We are waiting for the psychologists." If it is your problem because you seem to

be primarily interested in it, then it is a problem of economics. Go ahead and solve it.

One must not think that this gives an unfair advantage to the psychologists, relieving them from practically all responsibility for the welfare of the world. Not so. We psychologists have similar troubles. We are often inclined to think, this is a problem in physics, this is a problem in chemistry, this is a problem in neurology, and so forth, and to wait until the physicists, the chemists, the neurologists have solved it. But it won't do. Those men take but little interest in our problems. You can't expect them to take more. So we have to do what everyone has to do, to solve our own problems ourselves.

You do not wonder, then, altho you perhaps wondered before, why the modern psychologist needs so much equipment of apparatus, machinery, tools. Maybe you thought that a psychological laboratory ought to look like a saint's chapel or like the interior of the Egyptian temple which you saw on the operatic stage, in the Magic Flute. Such places seem to be well suited to an investigation of souls. But that is not our task.

CHAPTER XX

The Mysteries of the Soul.

Ask a college freshman on his registration day what he thinks his psychology teacher ought to teach him. The answer is likely to be "How to hypnotize people." Now, this is not mentioned in order to convey the idea that a psychologist is not concerned with hypnotism. We are. But this subject is so trite, and the task of hypnotizing a person is ordinarily so devoid of the satisfaction which comes from performing a task both difficult and useful (neither of which can usually be said of hypnotizing) that the psychologist feels no more enthusiasm about it than a kitchen chef would feel when given the task of boiling the potatoes for a banquet.

But with the layman it is a different story. It is thrilling. Why is there this great interest in hypnotism among the lay population? Because to them it is not a mere material event, as easily reproduced by anybody as any simple event, as sawing a branch from a tree, for example, but a demonstration of the powers of the soul. Like everything concerning the soul it is mysterious. And like everything mysterious it is thrillingly interesting.

Hypnotism is a relation between two human beings, two human bodies, two organisms. It is therefore a relation essentially the same as that of teacher and pupil, for example; or that of traffic policeman and driver; or that of a politician and his constituents; or that of the governor of a state and the people of the state; or that of an army officer and a soldier; or that of a priest and a confessing

sinner; or the relation between two sinners, or between two private soldiers, or that between one citizen and another one living next door. When we here enumerate these dry examples chosen at random from the multitude of human relations, they may at the first moment seem to be unsuited to our discussion, to involve nothing of the kind of a problem of souls. But with the least amount of reflection you will convince yourself that, except very recently, all these have always been treated, in the history of mankind, as problems of the interrelation of souls. And as problems of souls they have been mysterious problems, open to attack, not by the methods of science, but only by the methods of magic.

The most extreme case is that of religion. Let us therefore courageously subject it first to our scrutiny. Religion is to the individual who has it (and we all have religion, altho perhaps under different and curious names and at different times and periods of our lives different quantities of it)—religion is the great problem, the great mystery of our soul. How to procure satisfaction, salvation for our soul under the tribulations of life, that is the question. Does mankind draw the consequences from the fact that we know thru our senses no soul whatsoever, and that the only soul which we experience in our immediate consciousness is the own soul? If we drew the proper consequences, we would be—that is, mankind would always have been—perfectly tolerant in matters of religion. The reverse is true. Thruout history we find religion being spread by fire and sword, by torture and death. By these methods people believed themselves able to save, not only their own souls, but also thousands and millions of other souls. Innumerable human lives were sacrificed in order that their souls be saved.

Now assume, for comparison, the attitude of the modern psychologist. He will make no attempt at proving to you

that you have no soul. Your soul and the question of its existence are your own business. Because your soul is your own business, can never be any other's experience or business, and must therefore be forever mysterious, forever closed to the inductive methods of science, closed to the infinitely repeatable sensory-motor test of scientific procedure, therefore the psychologist minds his own business and leaves your soul alone. Your religion is to him a set of peculiar reactions of your body, consisting in the writing and speaking of particular words and the performance of particular observances, such as going to church.

The psychologist is much interested in these actions of your body. He tries to find out to what extent they are inherited, to what extent they are habits acquired during life, what forces, physical or social, contribute to the formation of these habits, what help your body can derive from these inherited and acquired functions in its struggle for existence. And then he will give you his advice.

You need not accept his advice. He will hardly urge you to accept it, for he knows how little he knows this complex machinery called the human body and its functions. As to forcing you by torture or death to accept his advice, the idea is ridiculous to him who knows how little he knows. The psychologist, altho he may have written a big volume on the psychology of religion, can not help being tolerant. He has as much doubt as he has knowledge.

It is the man who is interested in souls who is intolerant. Not having, since no one can have it (as we stated), scientific knowledge of other people's souls, he has no scientific doubts about their souls either, but regards them dogmatically as recasts of his own soul and acts accordingly. Is not that exactly what we call intolerance, when we expect everything to be like our own? He whose interest is centered in souls thinks, when he has forced others to speak

his prayer, pronounce his creed, kneel before his altar, that he has saved their souls, and fails to admit that he has merely forced their bodies,—without in the least trying to investigate the purpose, the end of his intolerant acts so far as the welfare of these bodies is concerned.

Religion is one of the poles of the axis around which our intolerance swings in its mysterious whirl. Government is the other. Naive thinkers have sometimes concluded that the easiest way of freeing the world from intolerance would be the abolition of both religion and government. Those who boast of being atheists, usually also boast of being anarchists. A certain phase in the French revolution comes to our mind as a typical example. If you still are in this naive stage of thought which often accompanies the enthusiasm of youth trying to reform the world quickly, we shall not take you seriously because we are convinced that you will sooner or later pass over that stage. What we must point out is that political terrorism, too, has its main and inexhaustible source in the human tendency to think of other human beings, not as bodies open to scientific investigation, but as souls, as mysterious beings, to be governed either by magic or, if magic fails as it naturally must, by torture and death.

In all the history of mankind it has always been regarded as the crime of all crimes to be against the de facto government, to be a rebel, to try to change the government by substituting for those persons who have the power, some other persons. If those who govern would be regarded and regard themselves merely as the servants of the people, why should it be a crime to change servants? We do it here in the United States every few years. But what is the divine right of kings if it is not the assertion of a mysterious soul given to the king by God, quite different from the souls

of subjects, but whose difference is quite beyond the possibility of scientific investigation.

Where the divine right is still quite unchallenged by the critical spirit of science, as among half civilized people, the king is expected to perform magic feats (in France until the eighteenth century). Why not,—if his soul is of a superior kind? One of the Prussian kings, even in the nineteenth century, made himself famous by speaking of "the limitations of judgment characteristic of mere subjects." Among more highly civilized people, where recognition of the fact that the body of the king (or say President, it makes no difference) is a very common human body interferes with regarding the soul as superior, an impersonal soul is often substituted and worshipped. It is the "state" or the "nation" or the "country" or the "honor of the flag," as we say, that plays the same role. Not the state in the sense of the totality of the human beings living within a certain territory in the year—choose your own. That would be a truly scientific conception in the investigation of which the psychologist would be glad to share. But the state in the sense of a soul-like reality, unknowable thru our senses, but which we must worship with out bodies as the subjects of a king worship their king.

In the story of William Tell it is said that the Governor whom the Emperor had sent to Switzerland invented a good method of making the Swiss submissive. He had a pole erected on the market place of one of the towns and his hat placed on top of the pole. When the Swiss people walked by, they had to take off their hats and bow. What were they to worship? The body of that piece of felt crowning the pole? Of course not, but its soul, the imperial idea. You see that even a piece of felt may have a soul. The story appears fanciful to us. It probably is fancy, a mere legend.

Make sure, however, that we do not do the same today, only under another name.

If we get into patriotic hysterics, the professional politician can subject us the more easily. In poetry one can not object to talk of the soul of a nation, or of such synonyms as the "honor" of a nation, which to some is as convenient a substitute for soul as it used to be to the duellists of former centuries who had to fight whenever their "honor" was hurt. Religion and poetry (or art in general) are the two forms of human activity which have a right to be unscientific—or rather extrascientific—so long as they are not antagonistic to scientific, objective social progress. But let this talk of the soul, the honor, the Kultur, the destiny of a nation and its needs get beyond the playful use in poetry, let it get into international diplomacy, let it begin to determine your actions towards other beings, and your actions will be as atrocious as those for which the world war has given us plentiful examples.

If nations could be made to see that all nations are congregations of organisms of the same species, and that what each calls its soul, its honor, its civilization, its tradition (the particular one of these terms used makes no difference) is only a set of organic habits on the whole neither better nor worse than the habits of another group, peace would reign on earth as it has come to reign in our smaller communities.

Let us recapitulate what we have said thus far. In religion and in politics the worst intolerance, the most inhuman atrocity is found correlated with the most one-sided preference of spiritual, subjective, idealistic terminology. Can you blame the psychologist when he, who regards the study of human life as his particular sphere of interest, confesses to you that he prefers to think of a human being

as a bodily organism rather than as a soul, of a nation as a society of such organisms rather than as a collective soul?

From our earliest youth, almost from infancy, we become saturated with habits of denoting human beings as souls, and thus we are led into the alleys of the maze of mystery from which few find their way out into the light of modern, rational, scientific thought, and from which many, very many, it is to be feared, never even see a dim and distant reflection of such light.

When you ask a person who manifests any considerable interest in psychology what it is that he is specially interested in, he usually replies that it is hypnotism, or thought transference, or mind reading, or fortune telling, or character reading. If this were not the twentieth century, but the eighteenth, we could have added sorcery, magic, enchantment. These and similar mixtures of fact and fable are the mysteries of the soul.

To hypnotize a person, it is necessary, according to the popular notion, to obtain first a peculiar property of the soul, a kind of spiritual magnetism that can at a distance act on another soul, can reproduce itself in another soul as magnetism can reproduce itself in another piece of iron, and which one may obtain therefore from another person who already has it, if that person is willing to give. No doubt that not a few college students are either entirely or at least partially driven by such notions and the motives connected therewith when they enroll in a course in psychology. Some people who offer themselves to play the ridiculous role of being hypnotized, do so from this kind of curiosity, because they wonder how it feels when that magnetism goes thru one. They are not to be blamed at all. If we grow up under conditions implanting such notions in us, it is entirely proper and an indication of a perfectly normal and desirable curiosity and ambition, to learn about and, if possible, ob-

tain such a wonderful power. On the other hand, it is easy to read the disappointment in their faces when they learn that everybody can hypnotize just as everybody can kindle a fire, can give an Indian whisky to drink, or can rock a baby to sleep. Why call it mysterious?

The following happened at a time when mysterious phenomena were most commonly referred to under the term "animal magnetism", when—in a certain European country—telegraph wires were already found along many of the important highways, but when railway lines were still very rare. The manager of an "animal magnetism show" traveled with his "medium" in a coach from one city to another. Unfortunately, when they arrived, they could not give the performance on the promised date because the medium had become sick. The manager explained the sickness very readily. No wonder she got sick: She, that is, this "lump of animal magnetism," had been compelled to "move for miles and miles parallel and in close proximity to an electric wire," that is, the telegraph wire. Many of our contemporaries who laugh at the foolishness of this explanation would probably be quite willing to accept equally foolish explanations of facts if they are only clad in terms which have the character of mysteriousness in the way in which the populace of today is accustomed to think.

Is there anything mysterious in a mother's rocking or singing a baby to sleep? It is just as difficult to rock a baby to sleep as to hypnotize a person. Nevertheless, no mother has ever claimed, and no other person has ever admitted, that she had a mysterious power over the baby's soul. The baby is placed in a comfortable position, the light is dimmed and all other avoidable stimuli are kept away. The subject to be hypnotized is treated in the same manner. The baby is rocked. Bodies to be hypnotized, however, are usually

too large and heavy to be rocked easily, since the hypnotizer is not a giant. Therefore the latter substitutes for the rocking talking. Speak to a person under such conditions as persuasively as you can about nothing but sleep and dreams, and he finally assumes the sleeping posture as far as it is possible in the given situation and becomes preoccupied with maintaining this posture.

If you have any experience in it, you know that, when you rock a baby to sleep, the most risky part of the performance is the moment when you stop rocking. The cessation of rocking requires a new adjustment of the baby's body and is therefore of the nature of a new stimulus. To this stimulus, the cessation of rocking, the baby is likely to respond by throwing about its arms and legs, by crying, and by similar activities which we familiarly call waking up.

What is to be emphasized, however, is not this waking up as such. If we must regard the cessation of rocking as a stimulus to which the baby's body responds by a new adjustment, it is clear that before the new and changed adjustment there was another adjustment. That is, the baby's body, asleep as we say, is nevertheless keeping adjusted, is in this way positively responding to the rocking, altho asleep. That is one of the false notions most people have, that sleep is the opposite of every class of activity. The sleeping body is not absolutely inactive. It is one-sidedly active. It is pre-occupied.

Now substitute for the baby the hypnotized subject. Talking takes the place of rocking. It is plain, then, that the hypnotized body, too, is still positively adjusting himself to, reacting to, the hypnotizer's talking,—altho already asleep. Now the hypnotizer begins to change the content of his talk. Instead of talking about sleep and dreams, he begins to talk about raising an arm, opening the mouth, and similar reactions of the nature of visible motion. But re-

member, the hypnotizer is one of those stimuli with whom the subject to be hypnotized is already preoccupied. It is not mysterious, then, that these motions are executed.

If I stand before an audience, raise my finger, look at it myself and say in a loud voice "Look at this finger," every one looks at it. There is no mystery in that. It is no more mysterious when a hypnotized person obeys an imperative demand and bites into a raw potato, smacks his lips, tells you that it is a delicious apple. If a clerk in the grocery store or a professional entertainer in the circus acts in that way, you call him silly, a fool, or a clown. Why,—be consistent and call the hypnotic performance by the corresponding name. It fully deserves it.

The only difference is this, that the clown is the actor who supplies the ridiculous element of the case, whereas in the hypnotic performance you, the spectator, little as you may suspect it, supply the ridiculous element. The preoccupied person can not be expected to act rationally while he is preoccupied, but you, the spectator, might have better sense than to apply the notion of a soul acting thru the medium of a spiritual magnetism, when all that happened before your eyes was the social relation, the most familiar fact in the world, between two bodily organisms. Think of two organisms, and the whole performance loses its mystery, becomes trivial. Think of two souls, and it is mysterious. But what is truly mysterious is the fact that you, a usually rational spectator, should apply this silly notion of a magnetism of souls.

The popular craving for hypnotism and whatever is connected with it becomes comprehensible when we recall that it is a craving for power,—for power over other souls, power to compel them to do what we want them to do. And people long for still another power over souls which consists in knowing them, in knowing their thoughts and

feelings, in knowing their character, in order to adjust themselves to such knowledge. If we could all realize that knowing another person can mean only knowing his organic habits, we would go about obtaining it in the proper way, by gradually accumulating experience, tho this process must be slow. But we think falsely that knowing another person means knowing his soul and crave for a short cut by mysterious means. In practice, the requirement of knowing another soul has played its greatest or rather its most disastrous role in criminal procedure.

Criminal procedure until most recent times has always had for its aim the restoration of the spiritual balance of the world by meting out punishment in proportion to the quantity of evil thought, of evil character, contained in the evil-doer's soul. That legal punishment is one of the means of social adaptation, of mutually adapting the habits of the individual human organism and of the society of such organisms, is a very recent insight which has not become quite universal yet. In the traditional procedure the only important problem for the judge was to know the accused person's soul, his "thoughts." When the prisoner's thoughts were known, it was an easy matter to adjust the punishment to them. Any person whose intelligence was equal to the multiplication table could do that.

But how to know the other person's thoughts,—that was a problem! Have you ever tried to read another person's mind? Suppose you were the judge and you had to read the other person's mind. Of course, you remember the classic examples of King Solomon. Go and do likewise. But you would soon begin to doubt, under the stress of actuality, whether Solomon's wisdom was not fable rather than fact. Mind reading is easy only when its truth or untruth is of no serious consequence, when it is a mere sport. It becomes difficult in proportion to its seriousness and its

real value. You can easily understand, then, why these judges of former centuries, despairing of their mysterious power of mind reading which they were supposed to possess, should have felt inclined to resort to a more feasible, altho cruel, method,—judicial torture. To listen is often easier than to read. Why not here?

Instead of reading, those judges decided to listen to, the prisoner's mind. If the prisoner's mind would not move his tongue, there were means of loosening the tongue—application to the prisoner's body of the thumb screw or the boot or the rack or the wheel. A person of the twentieth century, who is accustomed to scientific ways of thinking, and who regards the prisoner as an organism whose habits have to be studied, investigated by all possible means, among which listening to the prisoner's speech function is only one and not the most important means, wonders why former centuries should have placed such enormous weight in legal practice upon the prisoner's confession or lack of confession. But it becomes plausible enough when you consider that the judge in former times was not a sociologist, but a mind reader who by mind reading and a little knowledge of the law had to keep an imaginary, ideal, spiritual world from losing its balance. Fiat justitia, pereat mundus. Let justice be done, even tho the real world, that is, mankind, should perish.

Recall the horrors of the torture, the horrors of the procedure especially of such courts as the Spanish inquisition or the witch-craft courts of the 17th century in Europe and in New England,—the horrors of any and all criminal procedure down to the nineteenth, maybe even to the twentieth century.

These atrocities were due to the fact that the judge was serving as a mind reader, and that the accused was regarded primarily as a soul. Not even the most inhuman, most

bestial butcher (a butcher, of course, is not inhuman because of being a butcher) would treat a pig in that way. Why not?—Because the pig would be merely an animal, not a soul; and therefore not only the energy, but the dignity of the torture would be wasted on it. There are few cases reported in the history of mankind where animals, that is, "soulless" beings, have been executed; they seem to have entirely escaped judicial torture. Even that rooster, somewhere in Switzerland, that was burnt because eye witnesses seemed to prove that he had committed, about the year 1700, the devilish act of laying an egg, escaped previous torture before being burnt at the stake.

Nowadays we think we are more enlightened. We have abolished the rack. But how do we kill a prisoner condemned to death? We tell him that in a few weeks he must die, but we leave him in suspense as to whether tomorrow or next week. Then suddenly we give final notice, lead him in a formal procession to the electric chair and have a little chat with him as a crowning ceremony to our procedure. It does not occur to us that, if the welfare of society demands that a certain human organism be put to death, the only humane method would be putting him to death without telling him anything about it, or intimating as little as possible about it, and doing it in his sleep when he is not suspecting what will happen the next moment. Humane methods, however, we leave to the butcher. The executioner must be atrocious out of respect for the prisoner's soul.

The modern psychologist is not the man to whom you should appeal if you want information about your soul. The psychologist is not interested in your soul but in certain functions of your organism, in those which are directly of social significance, whereas he leaves to the physiologist, and the workers in branches of science related to physiology, the study of those functions of your organism which, like

digestion, or tissue growth, or the color of your hair, are not directly of social, but almost exclusively of individual significance. This book could have attempted to make clear the gradual change of his interests and its result, the present direction of the psychologist's interest. For example, it could have pointed out how men who started with a considerable enthusiasm for studying the soul became disgusted with this study, because they discovered that it led nowhere, just as this same study of the soul, continued for thousands of years in the history of mankind, practically led nowhere.

However, it is generally more difficult to prove the negative, the absence of something, than to prove the existence of something. So we chose the method which is easier and more quickly convincing, and tried to show you that our interest in other human beings as souls positively is highly dangerous for human society, that the most cruel acts of man against man are those committed in the name of man's mysterious soul, that a rational, a humane treatment of its individual members is to be expected much more by a society which regards itself as a group of organisms than by one which regards itself as a mysterious collective soul. You cannot, then, blame the psychologist if he refuses to be considered an expert in matters spiritual, if he proclaims that his work is a study of the human organism in certain functional aspects, as previously delimited.

QUESTIONS AND PROBLEMS

Chapter 1.

1. What role does the Self play in modern psychology?
2. Is the psychology of the Other-One a denial of his consciousness?
3. How do engines, plants, animals, and the Other-One differ?
4. What are the delimitations of psychology toward the other sciences?
5. What is the chief cause of animal locomotion?
6. What is the direct (not indirect and later) effect of a stimulus on living bodies?
7. What kinds of stimulation and what kinds of response are there?
8. What kinds of differentiated tissues must be distinguished?
9. What is the shape of neurons, and why?
10. What is the relative importance of gray and white matter?
11. What is the function of a ganglion cell?
12. What need is there of a second form of animal behavior?

Chapter 2.

13. What kind of snail are we considering?
14. Write a snail story in which you use the following terms as often as you wish, but in proper sequence: (1) body weight axis, (2) stimulus, (3) expansion, (4) conduction, (5) contraction, (6) excitation, (7) normal body shape, (8) deformation, (9) direction of body, (10) normal tissue density, (11) normal chemical constitution, (12) fever.
15. Why is the kind of nervous system which suggests itself most readily quite impossible?
16. Why must a moth, and all higher animals, have nervous tissue?
17. In what respect may the answers to questions 15 and 16 appear contradictory?
18. A nervous excitation causes, not only continuous muscular contraction, but what contraction also?

19. What is meant by sensory and motor points of the body? Are they geometrical points in the body?
20. Why do we call certain actions reflex actions?
21. What is the origin of the term "nerve center"?
22. What should we mean by central neurons, central sensory points. central motor points, peripheral points?

Chapter 3.

23. What is a local reaction?
24. What is a concerted action?
25. What distinction between causes must be made in concerted action?
26. Give examples showing the relativity of the distinction between local and concerted action.
27. Does reference to localness of an action imply inactivity of the rest of the body? What does it imply?
28. Do we mean by concertedness merely simultaneity?
29. What did the student who wrote "Odgen" write instead of "lapse"?
30. In the divisions of the bell of the jelly-fish, why is there little probability of much difference in frequency?
31. As in the preceding question, why is there some probability of some difference in frequency?
32. What is the disadvantage of a difference in frequency?
33. What insures simultaneity of contraction?
34. If the frequencies of the divisions, cut from each other, are 16, 12, 13, 14, 15, 13, 15, 14 per minute, why is the frequency of the united whole not the average, 14? What is it?
35. What, in the jelly-fish, serves as "conductor of the orchestra"?
36. Give an example of serial action.
37. Give an example of circular action.
38. How would you causally explain circular action?
39. Why can the explanation of circular action not be universally accepted as a causal explanation of serial action?

Chapter 4.

40. Is unification of the animal the one chief purpose of the existence of a nervous system?
41. What is the most general demand made on the architecture of the nervous system by concertedness of action?

42. In what respect can good conductivity from any part of an animal to every other be undesirable?
43. What are the two methods used by Nature in averting the predicament of "too universal conductivity"?
44. Which alone of the two methods referred to in the preceding question contains a constructive element valuable to the architect?
45. Why is the mere reflex path formerly mentioned not sufficient to enable a moth to alight on a twig or leaf?
46. What is the most useful diagram enabling us to represent short nervous connections between corresponding peripheral points and longer connections between non-corresponding points?
47. What is the unit by which we measure (count) the resistances of various paths in the diagram of nervous architecture?
48. How are resistance and conductivity related?
49. What is meant by "levels" in the nervous system?
50. Why are we (wrongly) inclined to represent a nerve center by a "point" from which neurons radiate?
51. Can excitations move thru any nervous path in either direction?
52. What facts of human behavior prove that excitations do not within the nervous system proceed toward sense organs?
53. What relation has the "synapse" to the last two questions?
54. How can the length of a conductor be responsible for a great delay of reaction, altho its length is virtually nothing in comparison with the velocity of the excitation?
55. What is the relation between the explanation of serial activity and the question of the number of nervous levels?
56. What is the advantage, in a diagram illustrating the last question, of representing "higher" nerve centers by arches with multiple legs rather than by radiating lines?
57. What are the three parts of the problem solved by choosing for the nervous system a design of "arches over arches"?
58. Compute the distribution of the flux in a nervous system differing from that for which the computation is made in the text only by the substitution for each of the three motor neurons (M^1_a M_a, M^1_b M_b, M^1_c M_c) of a pair of shunted

neurons.—Answers for the peripheral neurons: in-flux 1564; out-flux 49 and 49, 595 and 595, 138 and 138. But give the answers also for the central neurons as in the text.

Chapter 5.

59. Give examples showing that the Other-One's absent-mindedness is related to his just preceding occupation.
60. What is the synapse theory of preoccupation?
61. How may warming up be related to absent-mindedness?
62. What relation do lower and higher centers seem to have to absent-mindedness?
63. What is the positive aspect of a failure to act?
64. Give examples of the positive and the negative aspect of preoccupation.
65. What facts of behavior may be called competition of stimuli?
66. What advantage does Nature obtain thru competition of stimuli over what would result from the law of the resultant?
67. What physiological experiment proves the deflection of a weaker nervous current by a stronger one?
68. In what respects can a neuron be compared with a storage battery?
69. How does deflection differ from what the physiologists call inhibition?
70. What two functional peculiarities does the usage of language combine under the term "instinctive" activity?
71. Why must the "deflection center" in an instinctive activity be a "higher" center than the "overflow center," which is responsible for the concertedness?
72. Why is a room painted uniformly, lacking all decorative features, and placed in an absolutely silent locality by no means the ideal school room?
73. What are the three actual meanings of the social term "inattention"?
74. What is the cure for inattention?

Chapter 6.

75. What reflexes are joined, and how are they joined, in the candy-eating habit?
76. In what three ways do motor functions become related (logically) in the formation of habits?

77. Give an example not found in the text for each class referred to in the previous question.
78. What two terms are suggested in the text for the classes where there is not simply substitution?
79. Does the antagonism of muscles play any role in habit formation?
80. What two manners of reducing the resistance of a complete nervous path must be strictly distinguished? Which of these conductivity changes establishes itself most quickly and which lasts longest?
81. What three conditions are given in the text as essential for forming a habit replacing the motor function of one reflex by that of another?
82. What function discussed in the preceding chapter gives an advantage to simultaneous over successive stimulation in habit formation?
83. Illustrate the four meanings of "forgetting" referred to in the text by four stories not found in the text.
84. What does the text mean by positive and negative susceptibility of neurons?
85. In what ways (mentioned or not mentioned in the text) may "preoccupation" corrupt a "learning curve" or a "forgetting curve"?
86. What facts make it unavoidable to distinguish a specific conductivity (or resistance) of certain neurons from their general conductivity?
87. When do we call several stimuli similar, judging purely from the Other-One's motor activity, which we observe?
88. How does "similarity" depend on "specific resistance"?
89. How can a long path, after its resistance has been reduced, become shortened?
90. How may the shortening of the nervous path corrupt the learning curve?
91. Why is the difference between "persuading or tempting" and "training" the same as that between "willing" and "learning"?
92. Why do sociologists use the term "freedom" more frequently than physicists?
93. What concrete fact gives rise to the abstract term "strength of will"?

94. Under what conditions could the workman mentioned in the text (and under what conditions could he not) "will"?

Chapter 7.

95. What is the origin of the term "phrenology"?
96. Why does an animal have "ganglions"?
97. Why does not a worm show an upper and lower series of ganglions as clearly as it shows a right and left series?
98. Has a starfish one brain or five brains?
99. What is a brain?
100. Has a crayfish a brain?
101. Has a fish a brain?
102. Why has no animal its brain in the tail?
103. When in evolution a single ganglion increases in relative size continuously, what is the meaning of this growth?
104. Discuss the relative significance of three methods of comparing the average brain weights of two animal groups.
105. In the proper comparison of brain weights, how can one manage to get along without measuring the body surfaces?

Chapter 8.

106. What is the localizing reflex?
107. What is the logical opposite of localizing on the skin?
108. How many dimensions are there in the localizing reflexes of the eye and the ear?
109. Did you find in the text an old problem which is no problem?
110. What is negative localization?
111. What is the grasping reflex?
112. In what respect does the Other-One depend on combining the localizing and the grasping reflexes?
113. Enumerate the adjusting reflexes of the more conspicuous sense organs.
114. When do we not, and why do we not, localize a sound thru the medium of the localizing reflex? What do we use instead? And what is the use of having an auditory localizing reflex anyway?
115. What is the signaling reflex?
116. What advantage has acoustical over optical signaling?
117. Which are the muscle groups serving the Other-One's acoustical signaling?

118. What muscular contractions make up the sleeping reflex?
119. What is the stimulation in the case of the sleeping reflex?
120. State the two causes (other than incidental fatigue of his nervous system) of the sleeper's failure to converse with you readily.
121. Enumerate the eight forms of behavior which the text regards as fundamental and therefore inherited.
122. What is right-sidedness, and why is it discussed in this chapter? Is it a reflex, a habit, or neither?
123. Why is it impossible, by observing people a short time in their infancy, to foretell whether they will turn out right-sided or left-sided?
124. Is walking an inherited concerted action?
125. What reflex must combine itself with the habit of balancing in order to develop balancing into walking?
126. Compile a list of all the "human instincts" which you have heard of or read about in literature (other than this book) and reduce them to the eight fundamental classes of behavior recognized by the text as composing the Other-One's main inheritance.
127. When do we refer to reflexes as "emotions"?
128. Compile a list of all the "emotions" you know and reduce them to the eight fundamental classes of behavior plus such reflexes as you happen to remember even tho they are nowhere mentioned in the text on account of being on the whole only of secondary interest to the psychologist.
129. Is play a reflex? What is play?

Chapter 9.

130. Give a reason, other than the limitation of muscular accuracy, why Nature has established a rather large threshold of sensibility on the skin.
131. Why is the threshold the smaller, the greater the curvature of the surface region?
132. What reflex action or actions are replaced by the answer "Two" in cutaneous discrimination? And by the answer "One"?
133. How many dimensions has cutaneous space perception?
134. Make plain that space perception is a species of motor condensation in the nervous functioning.
135. Why is an "illusion" like an "emotion"?

Chapter 10.

136. What proves the existence of inherited visual space perception?
137. Demonstrate the dependence of nervous condensation on the size of the interval between stimulated points.
138. How do you explain that there is no real distinction possible between the "substitution" and the "addition" of a new reaction?
139. What habits has the Other-One with respect to angles in perspective?
140. What happens when areas in the visual field compete with mere points?
141. What examples can you give of two-dimensional or of color perceptions for which a third-dimensional localization is substituted?
142. Why does the Other-One call the moon larger when it is near the horizon?
143. Give examples of reflex actions (adjusting the sense organ) to which a localization in the third dimension is habitually added.
144. Is "single vision" or "double vision" simply a matter of mathematical correspondence or non-correspondence of retinal points stimulated?
145. Give examples of division of labor between corresponding retinal points.
146. Give an example of complete co-operation of corresponding retinal points.
147. Give examples of "wrestling" and of more or less compromising between corresponding retinal points.
148. What is the essential difference between the two visual images (both being two-dimensional space perceptions) of the two eyes?
149. How do you describe in words and in a drawing the lateral displacement for a farther and for a nearer object in stereoscopic vision?
150. Why does the perception of a puzzle picture change with difficulty?

Chapter 11.

151. Why must there be two kinds of excitations to be called forth by the intensity of the light? Why is one kind not sufficient?
152. What is the relation between a visual process and a visual substance?
153. How could a second visual substance be helpful to the animal world?
154. What proves that Nature, before dividing the spectrum in one definite point, experimented with different divisions?
155. In what sense is every normal retina color-blind?
156. What does it mean that the Blue excitation and the Yellow excitation are antagonistic?
157. What is meant by general adaptation of the retina?
158. What is successive induction?
159. What is simultaneous induction?

Chapter 12.

160. What mistake does Nature appear to have made in creating the second visual substance? And how did she remedy the defect?
161. It seems that Nature created the third visual substance somehow as God created woman. How?
162. How are the singular and dual colors related to the four excitations (or visual processes)?
163. What singular color does not exist in the rainbow?
164. Why are there only singular and dual, and not also plural colors?
165. Why does complementariness of colors interest the psychologist but little?
166. Why do the primary, principal, etc., colors of technology interest the psychologist but little?
167. How does a "flight of colors" come about?

Chapter 13.

168. What is the simplest kind of auditory organ?
169. What changes are needed in the auditory organ in consequence of leading the sound waves to the organ thru a tunnel?
170. Why are the "windows" located unsymmetrically to the tunnel?

171. What is the original purpose of the ear drum?
172. Why are the cavity and the partition lengthened?
173. What advantage results in pathological cases from the fact that the ear can function in more primitive and more advanced ways simultaneously?

Chapter 14.

174. What must happen to the stream of air exhaled in order to produce density changes directly, or to cause a solid body to vibrate and in turn produce the density changes?
175. What makes weak and irregular density changes strong and regular?
176. Which two may be said, generalizingly, to be the places where the stream of air is easily obstructed?
177. In what sense, and why, does great obstruction in the mouth preclude the production of "voiced" sounds?
178. What do we call speech during which the larynx never obstructs the stream of air?
179. Of what use in sound production is the mouth, and everything connected with it, aside from obstructing the passage of the air?
180. If whispering is one extreme, what is the other?
181. What is a syllable?
182. Are the consonants consonants and the vowels vowels in all languages?
183. Give examples showing how natural economy, laziness, and excitedness may influence the pronunciation.
184. What can be said about individuality in speaking?
185. Imitativeness is not a reflex, but—?
186. Are there inherited kinesthetic, olfactory, or gustatory imitative actions?
187. Are there inherited visual or auditory imitative actions?
188. How do auditory and other imitations change during life?
189. How is "serial activity" illustrated in speech?
190. Do the localizing and the sound signaling reflexes seem to be related?
191. What may happen when one speaks an unaccented language?

Chapter 15.

192. What do we mean, in psychology, when we call repeated motions rhythmical?
193. What used to be the chief argument for the belief that grouping in action was inherited?
194. What do you think of another person's "rhythm" when you hear him counting?
195. What habits of "rhythm" are rarely acquired? And why is that so?
196. By what procedure can an odd group most easily be developed from an even group?
197. Why is rhythm the most wonderful—perhaps the only true—example of transference of training?
198. What differences may be noted of the rhythm in dancing, poetry, music and prose?
199. Do laborers sing in order to make their work rhythmical?

Chapter 16.

200. What is generalizing as a bodily function of the Other-One?
201. What is the value of abstractions to the Other-One?
202. In what ways are generalization and abstraction aided by the invention of script?
203. What entirely new vocation is made possible as soon as generalization and abstraction have become established in the human race?
204. Give examples of special importance showing that, and to what extent, the progress of science depends on generalization and abstraction.
205. Is the acquisition of generalizations and abstractions different from the acquisition of other habits?
206. What is speculation?

Chapter 17.

207. Why are schools for deaf-born children more indispensable than schools for blind-born children?
208. What superstition existed in former centuries concerning deaf-born people?
209. What is the history of the education of the deaf?
210. Do animals think?

211. What corresponds in scientific psychology to the popular opposition of the mental and the physical in habits?
212. How does the education proceed of those who are born both blind and deaf?
213. What justifies our calling sight and hearing the higher senses?

Chapter 18.

214. Why is the literal meaning of "somnambulism" a misunderstanding of "sleep"?
215. In what respects are the actions of Lady Macbeth unusual?
216. Give examples of life histories demonstrating that abnormal preoccupation is not restricted to the functions of a particular high nerve center.
217. What does the transferability or transmutability of hysterical symptoms prove with respect to the question just hinted at (under 216) and with respect to deflection?
218. What proves that abnormal preoccupation does not readily extend to the functions of the lower centers?
219. What are the two fortunate indirect consequences of the freedom of reflexes from preoccupation?
220. Give various reasons for the wrong belief that hystericals are fond of telling lies?
221. How is hypnotism related to somnambulism?
222. What is personality?
223. Make a list of the anatomical and physiological conditions of a normal functioning of the human nervous system. Then derive from it a list of all possible abnormalities.

Chapter 19.

224. What is the wrong and the right meaning of a materialistic conception of history?
225. What is the speculative and the scientific conception of criminology?
226. What has kept sociology from submerging in speculation?
227. What is a psychology of religion?
228. Why is it unnecessary to define psychology?

Chapter 20.

229. Why would a general knowledge of modern psychology have prevented the cruelties of religious persecutions?

230. Why would a general knowledge of modern psychology prevent international atrocities?
231. Why would a general knowledge of modern psychology save people from the craving for hypnotism and similar phenomena?
232. Why would a general knowledge of modern psychology have prevented the cruelties of the criminal law.
233. What is human society and how does it concern the psychologist?

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